

3.3 Background Information on Groundfish Resources

3.3.1 Life History, Habitat, and Stock Status of Target Species

This section presents descriptions of major target species, summarizing important life history traits, their habitat environment, prey base, stock assessment, and status of the stocks. Additional information on life history (in table format) and habitat features (in mappings) for each major groundfish species are described in the following three documents: (1) environmental assessment for essential fish habitat (NPFMC 1999a), (2) essential fish habitat assessment report for the groundfish resources of the Bering Sea and Aleutian Islands (BSAI) region (NPFMC 1998a), and (3) essential fish habitat assessment report for the groundfish resources of the Gulf of Alaska (GOA) region (NPFMC 1998b).

3.3.1.1 Pollock

Stock Description and Life History

Pollock (*Theragra chalcogramma*) is the most abundant species within the eastern Bering Sea and the second most abundant groundfish stock in the GOA. It is widely distributed throughout the North Pacific Ocean in temperate and subarctic waters (Wolotira et al. 1993). Pollock is a semidemersal schooling fish, which becomes increasingly demersal with age. Approximately 50 percent of female pollock reach maturity at age four, at a length of approximately 40 cm. Pollock spawning is pelagic and takes place in the early spring on the outer continental shelf. In the eastern Bering Sea, the largest concentrations occur in the southeast, north of Unimak Pass. In the GOA, the largest spawning concentrations occur in Shelikof Strait and the Shumagin Islands (Kendall et al. 1996). Juvenile pollock are pelagic and feed primarily on copepods and euphausiids. As they age, pollock become increasingly piscivorous and can be highly cannibalistic, with smaller pollock being a major food item (Livingston 1991b). Pollock are comparatively short-lived, with a fairly high natural mortality rate estimated at 0.3 (Hollowed et al. 1997, Wespestad and Terry 1984) and maximum recorded age of around 22 years.

Although stock structure of Bering Sea pollock is not well defined (Wespestad 1993), three pollock stocks are recognized in the BSAI for management purposes: eastern Bering Sea, Aleutian Islands, and Aleutian Basin. Pollock in the GOA are thought to be a single stock (Alton and Megrey 1986) originating from springtime spawning in Shelikof Strait (Brodeur and Wilson 1996).

The Fishery

Pollock supports the largest fishery in Alaskan waters. In the BSAI, pollock comprise 75–80 percent of the catch. In the GOA, pollock constitute 25–50 percent of the catch. Fisheries management has restricted pollock to be harvested with pelagic trawl gear to minimize the potential interaction with other groundfish species and to reduce the magnitude of bottom disturbance. Pollock are also caught with bottom-trawl gear as bycatch from other fisheries.

The directed fishery for BSAI pollock is conducted by catcher-processors and catcher vessels using pelagic and bottom trawl gear. The season has traditionally been broken into two parts, a roe season during early winter, and a surimi (imitation crab) and filet season during the second half of the year. Currently, to minimize the potential indirect interaction with Steller sea lions (*Eumetopias jubatus*), the seasons have been managed to occur over broader areas and over seasons that are less contracted in time. Observed pollock fishery trawl locations in 1999 by season are shown in Figure 3.3-1.

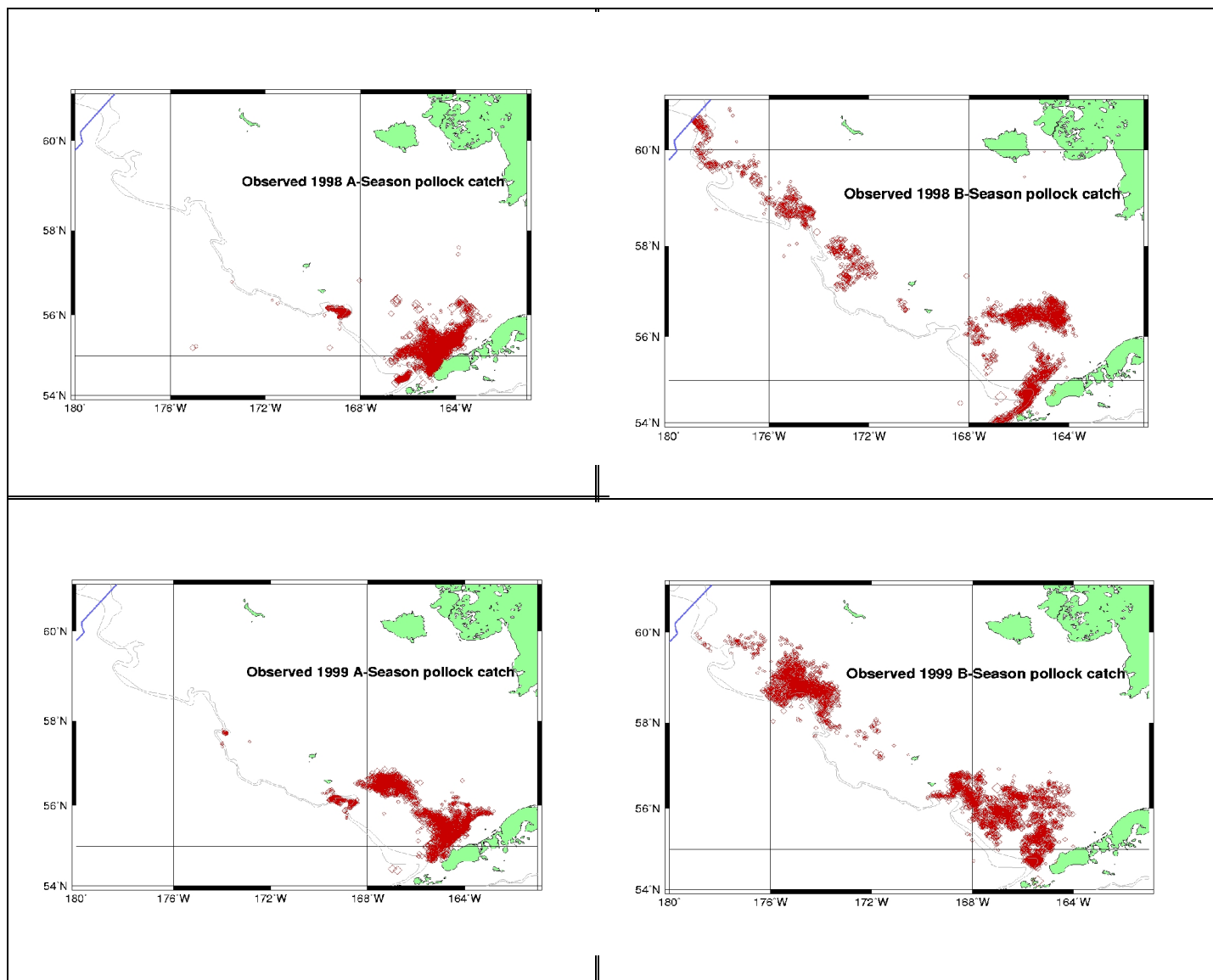


Figure 3.3-1 Distribution of fishery operations during 1998–1999. A-Season represents pollock caught during January 20–March 31, B-Season represents pollock caught during the second half of the calendar year. Source: NMFS

BSAI pollock are caught as bycatch in other directed fisheries, but because they occur primarily in well-defined aggregations, the impact of this bycatch is typically minimal. Recent discard rates through the early 1990s (discards/retained catch) of pollock in the directed fishery have been about 7–8 percent, but in 1998 dropped to 1.5 percent (Ianelli et al. 1999). This is because, in 1998, discarding of pollock was prohibited except in the fisheries where pollock are in bycatch-only status. Pollock are caught as bycatch in the trawl Pacific cod, rock sole, and yellowfin sole fisheries.

In the GOA, major exploitable concentrations are found primarily in the central and western regulatory areas (147°W–170°W). Pollock from this region are managed as a single stock that is separate from the BSAI pollock stocks (Alton and Megrey 1986). The pattern of the fishery generally reflects the broad spatial distribution of pollock throughout the central and western regions of the GOA. Shifts in the location of fishable concentrations of pollock reflect the seasonal migrations to spawning locations. The fishery generally occurs at depths between 100 and 200 m (Hollowed et al. 1997). Observed pollock fishery trawl locations in 1996 are shown in Figure 3.3-2. Important pollock fishery locations include Shelikof Strait, the canyon regions of the east side of Kodiak Island, and Shumagin Canyon.

Megrey (1989) documented the historical expansion of the pollock fishery in the GOA. He identified four phases of expansion, beginning with a developmental phase between 1964 and 1971 when the fishery was dominated by foreign trawlers that incidentally captured pollock in mixed-species catches. The second phase occurred between 1972 and 1980, when directed pollock harvests were initiated by foreign and joint-venture fisheries. Floating freezer-surimi trawlers were active in the GOA during the second phase of fishery development. The third phase of development occurred between 1981 and 1985. This phase was characterized by joint-venture operations. During this period, the Shelikof Strait spawning concentrations were discovered. Surimi production and roe harvest were emphasized during this phase of development. In recent years, foreign vessels have been eliminated from the pollock fishery. This final phase was marked by the passage of the inshore/offshore amendment, which mandated that 100 percent of the pollock catch be processed at shoreside plants. During this period the fishing community moved from a bottom trawl fishery to a mid-water fishery due to management measures established to control bycatch of prohibited species. Pacific halibut taken in the pollock fishery are added to the total for the shallow water complex halibut mortality cap. When the halibut cap is reached for the shallow water complex, trawling for species in the complex is prohibited, except for vessels using pelagic trawls.

Trophic Interactions

The diet of pollock in the eastern Bering Sea has been studied extensively (Dwyer 1984, Lang and Livingston 1996, Livingston 1991b, Livingston and DeReynier 1996, Livingston et al. 1993). These studies have shown that juvenile pollock is the dominant fish prey in the eastern Bering Sea. Other fish consumed by pollock include juveniles of Pacific herring, Pacific cod, arrowtooth flounder, flathead sole, rock sole, yellowfin sole, Greenland turbot, Pacific halibut, and Alaska plaice. On the shelf area, the contribution of these other fish prey to the diet of pollock tends to be very low (i.e., usually less than 2 percent by weight of the diet; (Livingston 1991b, Livingston and DeReynier 1996, Livingston et al. 1993). However, in the deeper slope waters, deep-sea fish (myctophids and bathylagids) are a relatively important diet component (12 percent by weight), along with euphausiids, pollock, pandalid shrimp, and squid (Lang and Livingston 1996).

The cannibalistic nature of pollock, particularly adults feeding on juveniles, is well documented by field studies in the eastern Bering Sea (Bailey 1989a, Dwyer et al. 1987, Livingston 1989, 1991b, Livingston and DeReynier 1996, Livingston and Lang 1997, Livingston et al. 1993). As mentioned previously, cannibalism by pollock in the Aleutian Islands region has not yet been documented (Yang 1996).

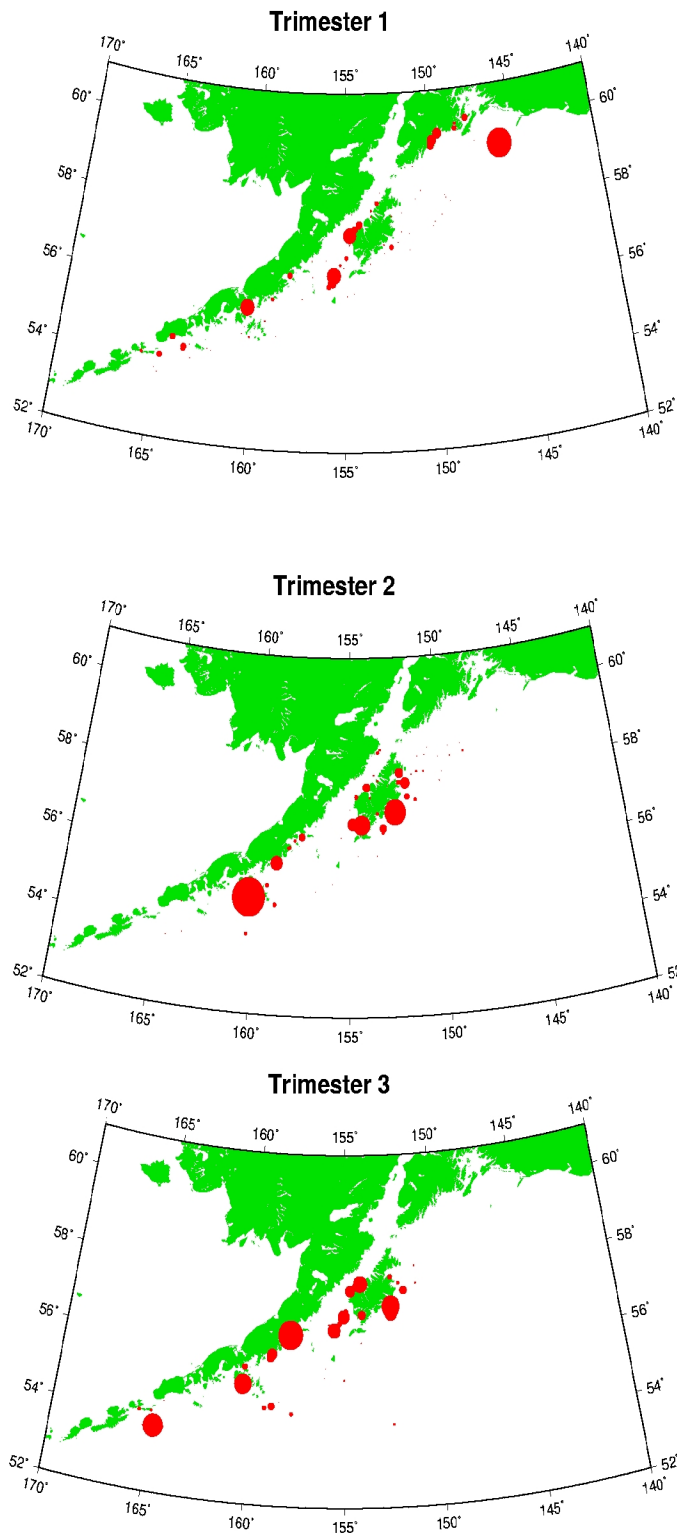


Figure 3.3-2 Distribution of observed trawl locations in the Gulf of Alaska where pollock was the target species, 1996. Source: NMFS

Cannibalism rates in the eastern Bering Sea vary depending on year, season, area, and predator size (Dwyer et al. 1987, Livingston 1989b, Livingston and Lang 1997). Cannibalism rates are highest in autumn, next highest in summer, and lowest in spring. Cannibalism rates by pollock larger than 40 cm are higher than those by pollock smaller than 40 cm. Most pollock cannibalized are age 0 and age 1 fish, with most age 1 pollock being consumed northwest of the Pribilof Islands where most age 1 pollock are found. Pollock larger than 50 cm tend to consume most of the age 1 fish. Smaller pollock consume mostly age 0 fish. Although age 2 and age 3 pollock are sometimes cannibalized, the frequency of occurrence of these age groups in stomach contents is quite low. Laboratory studies have shown the possibility of cannibalism among age 0 pollock (Sogard and Olla 1993a). Field samples have confirmed this interaction, but so far this interaction appears not to be very important.

Field and laboratory studies on juvenile pollock have examined behavioral and physical factors that may influence vulnerability of juveniles to cannibalism (Bailey 1989a, Olla et al. 1995, Sogard and Olla 1993a and 1993b). Although it had previously been hypothesized that cannibalism occurred only in areas with no thermal stratification, these recent studies show that age 0 pollock do move below the thermocline into waters inhabited by adults. Larger age 0 fish tend to move below the thermocline during the day, and all age 0 fish tend to inhabit surface waters for feeding at night. Most cannibalism may occur during the day. If food availability is high, all sizes tend to stay above the thermocline, but when food resources are low, even small age 0 fish move toward the colder waters as an energy-conserving mechanism. Thus, prediction of cannibalism rates may require knowledge of the thermal gradient and food availability to juveniles in an area.

Various studies have modeled pollock cannibalism in either a static or dynamic fashion (Dwyer 1984, Honkalehto 1989, Knechtel and Bledsoe 1981 and 1983, Laevastu and Larkins 1981, Livingston 1991a, and 1994, Livingston et al. 1993). The Knechtel and Bledsoe (1983) size-structured simulations produced several conclusions regarding cannibalism. Under conditions simulating the current fishing mortality rate ($F = 0.3/\text{yr}^{-1}$) the population tended toward equilibrium. They also found that cannibalism is a stabilizing influence, with the population showing less variation compared to simulations in which cannibalism was not included. Zooplankton populations were also simulated in the model, and Knechtel and Bledsoe concluded that food was limiting, particularly for adult pollock. Maximization of average catch occurred at an extremely high F value ($F = 3.0/\text{yr}^{-1}$), which is about ten times higher than the actual fishing mortality rates in the eastern Bering Sea. However, the interannual variation in catches under this hypothetical scenario were extremely large.

The trend in more recent modeling efforts (Honkalehto 1989, Livingston 1993 and 1994) has been to examine cannibalism using more standard stock assessment procedures such as virtual population analysis or integrated catch-age models such as Methot's (1990) synthesis model. The purpose is to obtain better estimates of juvenile pollock abundance and mortality rates, which can improve our knowledge of factors affecting recruitment of pollock into the commercial fishery at age 3. Results from Livingston (1993 and 1994) highlight several points with regard to cannibalism. In the current state of the eastern Bering Sea, cannibalism appears to be the most important source of predation mortality for age 0 and age 1 pollock. Predation mortality rates for juvenile pollock are not constant, as assumed in most population assessment models, but vary across time mainly due to changes in predator abundance but perhaps also due to predators feeding more heavily on more abundant year classes. The decline in pollock recruitment observed at high pollock spawning biomasses appears to be due to cannibalism. There also appears to be an environmental component to juvenile pollock survival (Wespestad and Dawson 1992), wherein surface currents during the first three months of life may transport larvae to areas more favorable to survival (e.g., away from adult predators or in areas more favorable for feeding). Estimates of total amount of pollock consumed by important groundfish predators show that cannibalism is the largest source of removal of juvenile pollock by groundfish predation (Livingston 1991a, Livingston and DeReynier 1996, Livingston et al. 1993).

Other groundfish predators of pollock include Greenland turbot, arrowtooth flounder, Pacific cod, Pacific halibut, and flathead sole (Livingston 1991a, Livingston and DeReynier 1996, Livingston et al. 1993 and 1993). These species are some of the more abundant groundfish in the eastern Bering Sea, and pollock constitute a large proportion of the diet for many of them. Other less abundant species that consume pollock include Alaska skate, sablefish, Pacific sandfish, and various sculpins (Livingston 1989a, Livingston and DeReynier 1996). Small amounts of juvenile pollock are even eaten by small-mouthed flounders such as yellowfin sole and rock sole (Livingston 1991a, Livingston and DeReynier 1996, Livingston et al. 1993). Age-0 and age-1 pollock are the targets of most of these groundfish predators, with the exception of Pacific cod, Pacific halibut, and Alaska skate, which may consume pollock ranging in age from age-0 to greater than age-6, depending on predator size.

Pollock is a significant prey item of marine mammals and birds in the eastern Bering Sea and has been the focus of many studies. Studies suggest that pollock is a primary prey item of northern fur seals when feeding on the shelf during summer (Sinclair et al. 1997 and 1994). Squid and other small pelagic fish are also eaten by northern fur seals in slope areas or in other seasons. The main sizes of pollock consumed by fur seals range from 3 to 20 cm for age 0 and age 1 fish. Older age groups of pollock may appear in the diet, during years of lower abundances of young pollock (Sinclair et al. 1997). Pollock has been noted as a prey item for other marine mammals including northern fur seals, harbor seals, fin whales, minke whales, and humpback whales but stomach samples from these species in the eastern Bering Sea have been very limited, so the importance of pollock in their diets has not been well-defined (Kajimura and Fowler 1984). Pollock are among the most common prey in the diet of spotted seals and ribbon seals which feed on pollock in the winter and spring in the areas of drifting ice (Lowry et al. 1997).

Five species of piscivorous birds are dominant in the avifauna of the eastern Bering Sea: northern fulmar, red-legged kittiwake, black-legged kittiwake, common murre, and thick-billed murre (Kajimura and Fowler 1984, Shuntov 1993). Pollock is sometimes the dominant component in the diets of northern fulmars, black-legged kittiwakes, common murre, and thick-billed murre, while red-legged kittiwakes tend to rely more heavily on myctophids (Hunt et al. 1981, Kajimura and Fowler 1984, Springer et al. 1986). Age 0 and age 1 pollock are consumed by these bird species, and the dominance of a particular pollock age-group in the diet varies by year and season. Fluctuations in chick production by kittiwakes have been linked to the availability of fatty fishes, such as myctophids, capelin, and Pacific sand lance (Hunt et al. 1995). Changes in the availability of prey, including pollock, to surface-feeding seabirds may be due to changes in sea surface temperatures and the locations of oceanographic features such as fronts, which could influence the horizontal or vertical distribution of prey (Decker et al. 1995, Springer 1992). See Section 3.5.2 for more information.

The diet of pollock, particularly adults, in the GOA has not been studied as thoroughly as in the eastern Bering Sea. Larvae, 5–20 mm in length, consume larval and juvenile copepods and copepod eggs (Canino 1994, Kendall et al. 1987). Early juveniles (25–100 mm) of pollock in the GOA primarily eat juvenile and adult copepods, larvaceans, and euphausiids; late juveniles (100–150 mm) eat mostly euphausiids, chaetognaths, amphipods, and mysids (Brodeur and Wilson 1996, Grover 1990a, Krieger 1985, Livingston 1985, Merati and Brodeur 1997, Walline 1983). Juvenile and adult pollock in southeast Alaska rely heavily on euphausiids, mysids, shrimp, and fish as prey (Clausen 1983). Euphausiids and mysids are important to smaller pollock and shrimp and fish are more important to larger pollock in that area. Copepods are not a dominant prey item of pollock in the embayments of southeast Alaska but appear mostly in the summer diet. Similarly, the summer diet of pollock in the central and western GOA does not contain as many copepods (Yang 1993). Euphausiids are the dominant prey, constituting a relatively constant proportion of the diet by weight across pollock sizes groups. Shrimp and fish are the next two important prey items.

In the GOA, fish prey become an increasing fraction of the pollock diet with increasing pollock size. Over 20 different fish species have been identified in the stomach contents of pollock from this area, but the dominant fish consumed is capelin (Yang 1993). A high diversity of prey fish were also found in pollock stomachs. Commercially important fish prey included Pacific cod, pollock, arrowtooth flounder, flathead sole, Dover sole, and Greenland halibut. Forage fish such as capelin, eulachon, and Pacific sand lance were also found in pollock stomach contents.

Dominant groundfish populations in the GOA that prey on pollock include arrowtooth flounder, sablefish, Pacific cod, and Pacific halibut (Albers and Anderson 1985, Best and St-Pierre 1986, Jewett 1978, Yang 1993). Pollock is one of the top five prey items (by weight) for Pacific cod, arrowtooth flounder, and Pacific halibut. Other prey fish of these species include Pacific herring and capelin (an *ø*merid fish). Other predators of pollock include great sculpins (Carlson 1995) and shortspined thornyheads (Yang 1993). As found in the eastern Bering Sea, Pacific halibut and Pacific cod tend to consume larger pollock, and arrowtooth flounder consume pollock that are mostly under age 3. Unlike the eastern Bering Sea, however, the main source of predation mortality on pollock at present appears to be from the arrowtooth flounder (Livingston 1994). Stock assessment scientists have attempted to incorporate predation mortality by arrowtooth flounder, Pacific halibut, and sea lions in the stock assessment for pollock in the GOA (Hollowed et al. 1997).

Research on the diets of marine mammals and birds in the GOA was less intensive than for the Bering Sea, but has recently been greatly accelerated (Brodeur and Wilson 1996, Calkins 1987, DeGange and Sanger 1986, Hatch and Sanger 1992, Lowry et al. 1989, Merrick and Calkins 1996, Pitcher 1980a, 1980b, 1981) (Section 3.5). Brodeur and Wilson's (1996) review summarized both bird and mammal predation on juvenile pollock. The main piscivorous birds that consume pollock in the GOA are black-legged kittiwakes, common murre, thick-billed murre, tufted puffins, horned puffins, and probably marbled murrelets. The diets of common murre have been shown to contain around 5 percent to 15 percent age 0 pollock by weight, depending on the season. The tufted puffin diet is more diverse and tends to contain more pollock than that of the horned puffin (Hatch and Sanger 1992). Both horned puffins and tufted puffins consume age 0 pollock. The amount of pollock in the diet of tufted puffins varied by region in the years studied, with very low amounts in the north-central GOA and Kodiak Island areas, intermediate (5–20 percent) amounts in the Semidi and Shumagin Islands, and large amounts (25–75 percent) in the Sandman Reefs and eastern Aleutian Islands. The proportion of juvenile pollock in the diet of tufted puffins at the Semidi Islands varied by year and was related to pollock year-class abundance.

Pollock is a major prey of Steller sea lions and harbor seals in the GOA (Merrick and Calkins 1996; Pitcher 1980a, 1980b, and 1981). Harbor seals tend to have a more diverse diet, and the occurrence of pollock in their diet is lower than in sea lions. Pollock is a major prey of both juvenile and adult Steller sea lions in the GOA. It appears that the proportion of animals consuming pollock increased from the 1970s to the 1980s, and this increase was most pronounced for juvenile Steller sea lions. Sizes of pollock consumed by Steller sea lions range from 5 to 56 cm, and the size composition of pollock consumed appears to be related to the size composition of the pollock population. However, juvenile Steller sea lions consume smaller pollock on average than adults. Age 1 pollock was dominant in the diet of juvenile Steller sea lions in 1985, possibly a reflection of the abundant 1984 year class of pollock available to Steller sea lions in that year.

Stock Assessment

Currently, information on pollock in the eastern Bering Sea comes from the National Marine Fisheries Service (NMFS) observers aboard commercial fishing vessels, annual trawl surveys, and triennial echo integration (hydroacoustic) trawl surveys. In the Aleutian Islands, information comes from observer data and triennial bottom trawl surveys. In the GOA, stock assessment information is based on observer and port sampling data,

annual hydroacoustic surveys in the Shelikof Strait area, and triennial bottom trawl surveys. These different data sets are analyzed simultaneously to obtain an overall view of each stock's condition. The bottom trawl data may not provide an accurate view of pollock distribution, because a significant portion of the pollock biomass may be pelagic and not available to bottom trawls and much of the Aleutian Islands shelf is untrawlable due to rough bottom.

In the eastern Bering Sea, pollock are assessed with an age-structured model incorporating fishery data and two types of survey catch data and age compositions. Bottom trawl surveys are conducted annually from June through August and provide a consistent time series of adult population abundance from 1982 to 1997. Echo-integrated trawl surveys are run every three years (typically) and provide an abundance index on more pelagic (typically younger) stock segments. Both surveys separate their catches into their relative age compositions prior to analyses. Fishery data include estimates of the total catch by area/time strata and the average body weight at age and relative age composition of the catch within each stratum. The results of the statistical model applied to these data are updated annually and presented in the BSAI pollock chapter of the North Pacific Fishery Management Council's (the Council) BSAI Stock Assessment and Fishery Evaluation (SAFE) report. Also included are separate analyses on pollock stocks in the Aleutian Islands and Bogoslof areas. These analyses are constrained by data limitations and are presented relative to the status of the eastern Bering Sea stock. This analysis focused specifically on the eastern Bering Sea stock with the view that extensions to these other areas are equally applicable. The stock assessment is reviewed by both the plan team and the Council's Scientific and Statistical Committee before being presented to the Council.

The estimated 2000 age composition of eastern Bering Sea pollock from the stock assessment model is shown in Figure 3.3-3. Ages 4 through 15 represent the recruited population. The age composition has been dominated by strong year classes—most recently there appears to be a higher-than-average year-class for 1992; prior to that, the 1989 year class was very high. The abundance of these year classes is evident from the echo integration trawl (EIT) and bottom trawl surveys, in addition to the extensive fishery age-composition data that have been collected. The selectivity of the fishery has cumulative impacts on the age composition due to fishing mortality. The fishery has tended to exhibit variable selectivity over time, but generally targets fish aged 5 years and older.

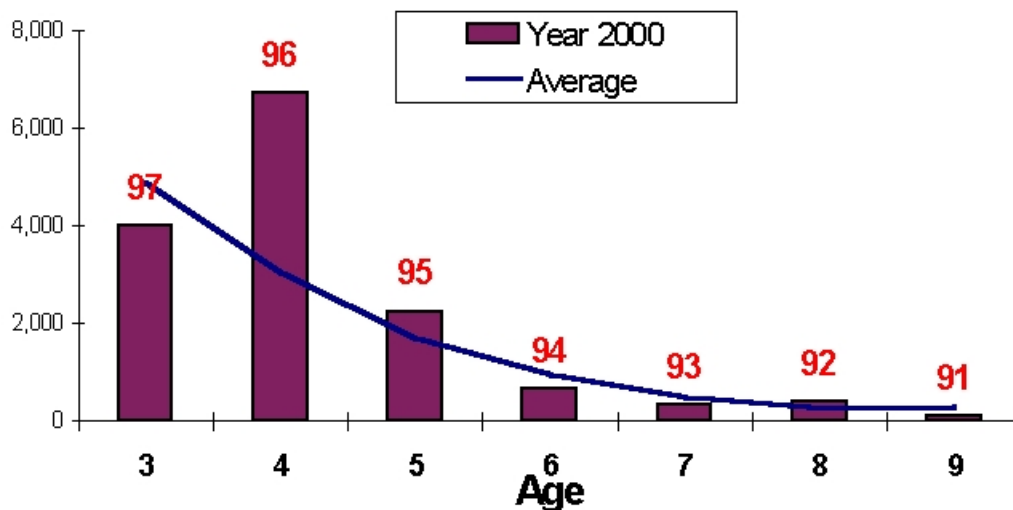


Figure 3.3-3 Projected age distribution (year classes noted on top of bars) and long-term average (solid line) for eastern Bering Sea pollock, 2000. Source: NMFS

GOA pollock are also assessed with an age-structured model incorporating fishery and survey data. The data used in this analysis consist of estimates of total catch biomass, bottom trawl biomass estimates, EIT survey estimates of the spawning biomass in Shelikof Strait, egg production estimates of spawning biomass in Shelikof Strait, and fisheries catch at age and survey size compositions. Fishery catch statistics (including discards) are estimated by the NMFS Alaska Regional Office. These estimates are based on the best blend of observer-reported catch and weekly production reports. Age composition data are obtained from several sources, including catch at age aggregated over all seasons, nations, vessel classes, and International North Pacific Fisheries Commission (INPFC) statistical areas for the years, and catch at age from the spring EIT survey and the bottom trawl surveys. An additional estimate of the age composition of the population in 1973 was available from a bottom trawl survey of the GOA. Length frequency data collected from the EIT survey are also included in the model, as is historical information on pollock size composition obtained from the Japanese Pacific ocean perch fishery from the period 1964–1975 (Hollowed et al. 1991). Recent assessments have explored the impact of predation mortality by arrowtooth flounder, Pacific halibut, and Steller sea lions by incorporating time series of estimated predator biomass, the age composition of pollock consumed by predators, and estimated consumption rates (Hollowed et al. 1997).

The current age and size distributions of GOA pollock are discussed in Hollowed et al. (1997). The estimated 1997 age composition of pollock from the stock assessment model is shown in Figures 3.3-4 and 3.3-5. Ages 3 through 15 represent the recruited population, although reliable estimates of abundance for ages 2 and above exist. The age composition was dominated by strong 1994 year class; large numbers from the strong 1988 year class were still in the population. The estimated mean age of the recruited portion of the population in 1999 was 4 years.

Over the last 15 years, NOAA's Fisheries Oceanography Coordinated Investigations (FOCI) targeted much of their research on understanding processes influencing recruitment of pollock in the GOA. These investigations led to the development of a conceptual model of factors influencing pollock recruitment (Kendall et al. 1996). Bailey et al. (1996) reviewed 10 years of data for evidence of density dependent mortality at early life stages. Their study revealed evidence of density dependent mortality only at the late larval to early juvenile stages of development. Bailey et al. (1996) hypothesize that pollock recruitment levels can be established at any early life stage (egg, larval, or juvenile) depending on sufficient supply from prior stages. They labeled this hypothesis the supply dependent multiple life stage control model. In a parallel study, Megrey et al. (1996) reviewed data from FOCI studies and identified several events that are important to pollock survival during the early life history. These events are climatic events (Hollowed and Wooster 1995, Stabenot et al. 1995), preconditioning of the environment prior to spawning (Hermann et al. 1996), the ability of the physical environment to retain the planktonic life stages of pollock on the continental shelf (Bograd et al. 1994, Schumacher et al. 1993), and the abundance and distribution of prey and predators on the shelf (Bailey and Macklin 1994, Canino 1994, Theilacker et al. 1996). Thus, the best available data suggest that pollock year-class strength is controlled by sequences of biotic and abiotic events and that population density is only one of several factors influencing pollock production.

In both the BSAI and the GOA, cumulative impacts of fishing mortality on age composition are influenced by the selectivity of the fishery. The current age compositions of the stocks reflect a fished population with a long catch history. In any given year, the age composition of the stock is influenced by previous year-class strength. The reproductive potential of the stock in a given year depends on the biomass of spawners, as modified by abiotic and biotic conditions. Thus, the average age of unfished populations are likely to have varied interannually due to oceanic and climate conditions. The NMFS's FOCI and the Coastal Ocean Program's Southeast Bering Sea Carrying Capacity (Southeast Bering SeaCC) regional study focuses research on improving understanding of mechanisms underlying annual production of pollock stocks in the GOA and eastern Bering Sea. NOAA's long-term goal is to improve the ability to assess quantitatively the long-term

impact of commercial removals of adult pollock on future recruitment by combining the findings of process-oriented research programs such as FOCI and Eastern Bering Sea CC with NMFS's ongoing studies of species interactions, fish distributions, and abundance trends. This supplemental environmental impact statement (SEIS) does not seek to evaluate the range of mean ages that could have occurred in the absence of fishing.

Acceptable Biological Catch as Recommended in the Most Recent Stock Assessments

Eastern Bering Sea pollock fell into Tier 3a of the acceptable biological catch (ABC) and overfishing levels (OFL) definitions in 1999, which require reliable estimates of biomass, $B_{40\%}$, and fishing mortality, $F_{35\%}$ and $F_{40\%}$. Under the definitions and current stock conditions, the overfishing fishing mortality rate is the $F_{35\%}$ rate, which is 0.65 for pollock and equates to a yield of 1.5 million metric tons (mt) (Ianelli et al. 1999). The ABC (using $F_{ABC} = F_{40\%}$) for pollock gives a yield of 1.139 million mt. This total allowable catch (TAC) was set equal to the ABC value, recognizing that the $F_{40\%}$ rate was well below estimates made for F_{MSY} . This lower level has been adjusted downward to provide a conservative harvest rate, which more accurately reflects the degree of uncertainty.

In 1999, GOA pollock fell into Tier 3 of the ABC/OFL definitions, which require reliable estimates of biomass, $B_{40\%}$, and fish mortality $F_{30\%}$ and $F_{40\%}$. Under the definitions and current stock conditions, the overfishing rate is the fishing mortality rate that reduces the spawner stock biomass to 35 percent of its unfished level (the $F_{35\%}$ rate). In 1999, the full recruitment fishing mortality $F_{35\%}$ rate was 0.50 for pollock and equated to a yield of 130,758 mt for 2000 for the central and western GOA (Dorn et al. 1999). The projected 2000 spawning stock biomass fell below $B_{40\%}$; therefore, the maximum allowable fishing mortality rate for ABC (F_{ABC}) was the adjusted $F_{40\%}$ rate 0.34 (Dorn et al. 1999). This F_{ABC} translated to a yield projection of 111,306 mt in 2000 for the western and central regions. The 2000 Council ABC level was 100,000 mt for the western and central regions, which was equivalent to the recommended stock assessment ABC, and equivalent to the TAC. Current harvest rates were set to ensure a healthy spawning stock, large enough to ensure successful recruitment over long time and recruitment variations.

<u>2000 ABC</u>	<u>2000 TAC</u>	<u>1999 Catch</u>
1,139,000 (BSAI)	1,139,000 (BSAI)	890,500 (BSAI)
100,000 (GOA)	100,000 (GOA)	93,400 (GOA)

3.3.1.2 Pacific Cod

Stock Description and Life History

Pacific cod is a demersal species that occurs on the continental shelf and upper slope from Santa Monica Bay, California through the GOA, Aleutian Islands, and eastern Bering Sea to Norton Sound (Bakkala 1984). The Bering Sea represents the center of greatest abundance, although Pacific cod are also abundant in the gulf and Aleutian Islands. GOA, Bering Sea, and Aleutian Islands cod stocks are genetically indistinguishable (Grant et al. 1987), and tagging studies show that cod migrate seasonally over large areas (Shimada and Kimura 1994).

In the late winter, Pacific cod converge in large spawning masses over relatively small areas. Major aggregations occur between Unalaska and Unimak Islands, southwest of the Pribilof Islands, and near the Shumagin group in the western GOA (Shimada and Kimura 1994). Spawning takes place in the sublittoral-bathyal zone near the bottom—the area of the continental shelf and slope about 40–290 m deep. The eggs sink to the bottom and are somewhat adhesive (Hirschberger and Smith 1983).

Figure 3.3-4 Estimated population at age for walleye pollock in the western and central regulatory areas of the Gulf of Alaska, 1990–1997. Source: NMFS

Figure 3.3-5 Estimated population at age for walleye pollock in the western and central regulatory areas of the Gulf of Alaska, 1972–1979. Source: NMFS

Pacific cod reach a maximum recorded age of 19. Estimates of natural mortality vary widely, ranging from 0.29 (Thompson and Shimada 1990) to 0.83–0.99 (Ketchen 1964). For stock assessment purposes, a value of 0.37 is used in both the BSAI (Thompson et al. 1999) and the GOA (Thompson and Dorn 1999). In the BSAI, 50 percent of Pacific cod are estimated to reach maturity by the time they reach 67 cm in length, or an age of about 5 years (Thompson and Dorn 1999). The same length in the GOA stock corresponds to an age of about 7 years (Thompson et al. 1999).

Trophic Interactions

Pacific cod are omnivorous. In the BSAI and GOA, in terms of percent occurrence, the most important items were polychaetes, amphipods, and crangonid shrimp. In terms of numbers of individual organisms consumed, the most important items were euphausiids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, the most important items were pollock, fishery offal, and yellowfin sole. Small Pacific cod were found to feed mostly on invertebrates, while large Pacific cod are mainly piscivorous (Livingston 1991b). Predators of Pacific cod include halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffins (Westrheim 1996).

Fishery

The Pacific cod fishery is the second largest Alaskan groundfish fishery. In 1999, Pacific cod constituted 12 percent of the groundfish catch in the BSAI and 30 percent of the groundfish catch in the GOA. The fishery for Pacific cod is conducted with bottom trawl, longline, pot, and jig gear. Of these, the fishery conducted with jig gear is by far the smallest. More than 100 vessels participate in each of the three larger fisheries. The age at 50 percent recruitment varies between regions. For trawl, longline, and pot gear, the age at 50 percent recruitment in the eastern Bering Sea is approximately four, four, and five years, respectively (Thompson and Dorn 1999). For all three gears, the age at 50 percent recruitment in the GOA is approximately six years (Thompson et al. 1999). The trawl fishery is typically concentrated during the first few months of the year, whereas fixed-gear fisheries may sometimes run essentially year-round. Bycatch of crab and halibut often causes the Pacific cod fisheries to close prior to reaching the TAC. In the eastern Bering Sea, trawl fishing is concentrated immediately north of Unimak Island, whereas the longline fishery is distributed along the shelf edge to the north and west of the Pribilof Islands. In the GOA, the trawl fishery has centers of activity around the Shumagin Islands and south of Kodiak Island, while the longline fishery is located primarily in the vicinity of the Shumagins. Pacific cod is also taken as bycatch in a number of trawl fisheries. In the eastern Bering Sea, Pacific cod is taken as bycatch in the trawl fisheries for pollock, yellowfin sole, and rock sole. In the Aleutian Islands region, Pacific cod is taken as bycatch in the trawl fishery for Atka mackerel. In the GOA, Pacific cod is taken as bycatch in the trawl fisheries for shallow water flatfish, arrowtooth flounder, and flathead sole. Since 1998, discarding of Pacific cod has been prohibited except fisheries in which Pacific cod has bycatch only status.

Stock Assessment

Beginning with the 1993 BSAI SAFE report (Thompson and Methot 1993) and the 1994 GOA SAFE report (Thompson and Zenger 1994), a length-based synthesis model (Methot 1990) has formed the primary analytical tool used to assess Pacific cod. Although the Pacific cod stocks in the eastern Bering Sea and GOA are modeled separately, the model structures in recent years have been identical (Thompson and Dorn 1999, Thompson et al. 1999). No formal assessment model exists for the Aleutian Islands portion of the BSAI stock. Instead, results from the eastern Bering Sea assessment are inflated proportionally to account for Aleutian Islands fish.

Annual trawl surveys in the eastern Bering Sea and triennial trawl surveys in the Aleutian Islands and GOA are the primary fishery-independent sources of data for Pacific cod stock assessments (Thompson and Dorn 1999, Thompson et al. 1999). For the most recent assessments, fishery size compositions were available, by gear, for the years 1978 through the first part of 1997. The catch history was divided into two portions, determined by the relative importance of the domestic fishery. A *pre-domestic* portion was defined as those years in which the domestic fishery took less than half the catch, and a *domestic* portion was defined as those years in which the domestic fishery took at least half the catch. Within each year (in both portions of the time series), catches were divided according to three time periods: January–May, June–August, and September–December. This particular division, which was suggested by participants in the eastern Bering Sea fishery, is intended to reflect actual intra-annual differences in fleet operation (e.g., fishing operations during the spawning period may be different than at other times of year). Four fishery size composition components were included in the likelihood functions used to estimate model parameters: the period 1 trawl fishery, the periods 2–3 trawl fishery, the longline fishery, and the pot fishery. In addition to the fishery size composition components, likelihood components for the size composition and biomass trend from the bottom trawl surveys were included in the model. All components were weighted equally.

Quantities estimated in the most recent stock assessments include parameters governing the selectivity schedules for each fishery and survey in each portion of the time series, parameters governing the length-at-age relationship, population numbers at age for the initial year in the time series, and recruitments in each year of the time series. Given these quantities, plus parameters governing natural mortality, survey catchability, the maturity schedule, the weight-at-length relationship, and the amount of spread surrounding the length-at-age relationship, the stock assessments reconstruct the time series of numbers at age and the population biomass trends (measured in terms of both total and spawning biomass). The model around which the most recent Pacific cod assessments are structured uses an assumed survey catchability of 1.0 and an assumed natural mortality rate of 0.37. Other outputs of the assessments include projections of biomass and harvest under a variety of reference fishing mortality rates. Based on these projections, the scientists responsible for conducting the assessments recommend a pair of ABC values for the coming year (one value for the BSAI and one for the GOA).

Pacific cod is currently managed under Tier 3 of the Council's ABC and OFL definitions (Amendment 56 to each of the respective fishery management plans [FMPs]). Management under Tier 3 requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC), and $F_{35\%}$ (for OFL).

ABC as Recommended in the Most Recent Stock Assessments

Under Tier 3 of Amendment 56 to the BSAI and GOA groundfish FMPs, the maximum permissible ABC depends on the relationship of projected spawning biomass to $B_{40\%}$. For the BSAI, the base model in the 1999 assessment projected a 2000 spawning biomass of 355,000 mt, about 6 percent below the $B_{40\%}$ estimate of 379,000 mt, leading to a maximum permissible ABC of 206,000 mt (Thompson and Dorn 1999). For the GOA, the base model in the 1999 assessment projected a 2000 spawning biomass of 111,000 mt, about 12 percent above the $B_{40\%}$ estimate of 98,800 mt, leading to a maximum permissible ABC of 86,000 mt (Thompson et al. 1999). To determine whether ABC should be set at the maximum permissible level, the 1999 assessments presented a decision-theoretic analysis of the statistical uncertainty surrounding the respective model's projected $F_{40\%}$ catch level, specifically the uncertainty associated with the assumed values of the natural mortality rate ($M = 0.37$) and survey catchability coefficient ($q = 1.0$). These analyses resulted in a recommended 2000 ABC of 193,000 mt for the BSAI and 76,400 mt for the GOA.

<u>2000 ABC</u>	<u>2000 TAC</u>	<u>1999 Catch</u>
193,000 (BSAI)	193,000 (BSAI)	174,000 (BSAI)
76,400 (GOA)	59,800 (GOA, excluding state waters)	73,600 (GOA)

3.3.1.3 Flathead Sole

Flathead sole (*Hippoglossus elassodon*) is distributed from northern California northward throughout Alaska (Wolotira et al. 1993). In the northern part of its range, it overlaps with the related and very similar Bering flounder (*Hippoglossoides robustus*) (Hart 1973). Because it is difficult to separate these two species at sea, they are currently managed as a single stock (Walters and Wilderbuer 1997). Adults are benthic and occupy separate winter spawning and summer feeding distributions. From overwintering grounds near the continental shelf margin, adults begin a migration onto the mid and outer continental shelf in April or May. The spawning period occurs in the spring, primarily in deeper waters near the margins of the continental shelf (Walters and Wilderbuer 1997). Eggs are large and pelagic. Upon hatching, the larvae are planktonic and usually inhabit shallow areas (Waldron and Vinter 1978). Exact age and size at maturity are unknown, but recruitment to the fishery begins at age 3. The maximum age for flathead sole is approximately 20 years. An estimated natural mortality rate of .20 is used for stock assessment (Turnock et al. 1997a, Waldron and Vinter 1978). Flathead sole feed primarily on invertebrates such as amphipods and decapods. In the eastern Bering Sea, other fish species represented 5–25 percent of the diet (Livingston et al. 1993). Flathead sole are taken in bottom trawls both as a directed fishery and in pursuit of other bottom dwelling species.

The following information is available to assess the unit stock condition:

<u>Data Component</u>	<u>Years of Data</u>
Fishery catch (volume)	1977–1999
Foreign fishery (size composition data)	1977–1989
Domestic fishery (size composition data)	1990–1998
NMFS trawl survey (est. biomass estimates and std. error)	1982–1999
NMFS trawl survey (size composition data)	1982–1999
NMFS trawl survey (age composition data)	1982, 1985, 1992, 1995

Annual trawl survey biomass results have been the primary data component used to assess stock level since 1982, although all the above information was also input into a length-based stock assessment model (Spencer et al. 1999). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels which, when considered with projected future biomass, are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE report.

Flathead sole are currently managed under Tier 3 of the Council's ABC and OFL definitions (Amendment 44 to the FMP). Management under Tier 3 requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC), and $F_{35\%}$ (for OFL). Since the projected flathead sole female spawning biomass for 2000 is greater than $B_{40\%}$ ($261,300 > 133,800$), $F_{40\%}$ (the upper limit on ABC), is recommended as the F_{ABC} harvest reference point for 2000. The 2000 TAC is well below the ABC and the 1999 catch was only 23 percent of the 1999 TAC, as follows:

BSAI 2000 ABC

73,500

BSAI 2000 TAC

52,652

BSAI 1999 Catch

17,777

For information on flathead sole assessment in the GOA see Section 3.3.1.8.

3.3.1.4 Rock Sole

Rock sole are distributed from southern California northward through Alaska (Wolotira et al. 1993). Two species of rock sole occur in the North Pacific Ocean, a northern rock sole (*Lepidopsetta* sp. cf. *bilineata*), and a southern rock sole (*L. bilineata*). These species have an overlapping distribution in the GOA, but the northern species primarily comprise the BSAI populations, where they are managed as a single stock (Wilderbuer and Walters 1997). Adults are benthic and, in the eastern Bering Sea, occupy separate winter (spawning) and summertime feeding distributions on the continental shelf. Spawning takes place during the late winter-early spring, near the edge of the continental shelf at depths of 125 to 250 m. Eggs are demersal and adhesive (Forrester 1964). The estimated age at 50 percent maturity for female rock sole is 9–10 years at a length of 35 cm (Wilderbuer and Walters 1997b). The best estimate for natural mortality is 0.18 for the BSAI (Wilderbuer and Walters 1992) and 0.20 for the GOA (Turnock et al. 1997a). Rock sole are important as the target of a high-value bottom trawl roe fishery occurring in February and March, which accounts for the majority of the BSAI catch. Although female rock sole are highly desirable when in spawning condition, large amounts are discarded in other trawl fisheries during the rest of the year. Commercial harvest occurs primarily on the eastern Bering Sea continental shelf and in lesser amounts in the Aleutian Islands.

Northern and southern rock sole are managed as a single unit in the BSAI. Rock sole are abundant on the eastern Bering Sea shelf and to a lesser extent in the Aleutian Islands. This species represents a data-rich case, in which the following information is available.

<u>Data Component</u>	<u>Years of Data</u>
Trawl fishery (data catch at age)	1980–1998
Trawl surveys (population age composition)	1975, 1979–1998
Fishery catch (volume)	1975–1999
Trawl survey (est. biomass estimates and std. error)	1982–1999
Trawl surveys (maturity schedule)	1993–1994
Trawl surveys (mean weight at age)	1985–1988

The time-series of fishery and survey age compositions allows the use of an age-based stock assessment model as the primary analytical tool (Wilderbuer and Walters 1999). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels, which, when considered with projected future biomass, are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE report.

Rock sole are currently managed under Tier 3 of the Council's ABC and OFL definitions (Amendment 44 to the FMP). Management under Tier 3 requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC) and $F_{35\%}$ (for OFL). Since the projected rock sole female spawning biomass for 2000 is greater than $B_{40\%}$

(675,500 > 284,700), $F_{40\%}$ (the upper limit on ABC), is recommended as the F_{ABC} harvest reference point for 2000.

<u>BSAI 2000 ABC</u>	<u>BSAI 2000 TAC</u>	<u>BSAI 1999 Catch</u>
230,000 mt	134,760 mt	40,362 mt

For information on rock sole assessment in the GOA, see Section 3.3.1.8.

3.3.1.5 Greenland Turbot

Greenland turbot (*Reinhardtius hippoglossoides*) are distributed from Baja California northward throughout Alaska, although they are rare south of Alaska and primarily distributed in the eastern BSAI (Hubbs and Wilimovsky 1964). Juveniles are believed to spend the first three or four years of life on the continental shelf, then move to the continental slope as adults (Alton et al. 1988, Templeman 1973). Greenland turbot are demersal to semipelagic. Unlike most flatfish, the Greenland turbot's migrating eye does not move completely to one side, but stops at the top of the head, which presumably results in a greater field of vision and helps to explain this species' tendency to feed off the sea bottom (de Groot 1970). Spawning occurs in winter and may be protracted, starting as early as September and continuing until March (Bulatov 1983). The eggs are benthypelagic (suspended in the water column near the bottom) (D'yakov 1982). Juveniles are absent in the Aleutian Islands, suggesting that populations in that area originate from elsewhere (Alton et al. 1988). Greenland turbot are a moderately long-lived species, with a maximum recorded age of 21 years (Ianelli and Wilderbuer 1995) and an estimated natural mortality rate of 0.18 (Ianelli et al. 1997). Pelagic fish are the main prey of Greenland turbot, with pollock often a major species in the diet (Livingston 1991b). Greenland turbot also feed on squid, euphausiids, and shrimp.

Abundance of juvenile Greenland turbot is estimated in the eastern Bering Sea by an annual trawl survey and in the Aleutian Islands by a triennial trawl survey. Abundance of adults has been estimated by trawl slope surveys conducted cooperatively by the United States and Japan. In the GOA, abundance is estimated by the triennial trawl survey. A lack of deep water samples, however, creates a high degree of uncertainty for these estimates (Turnock et al. 1997b). The biomass of Greenland turbot in the BSAI increased during the 1970s and is currently estimated to be about half of the unfished level. A lack of recruitment success during recent years has led to extra caution in setting harvest levels. Greenland turbot is a relatively valuable species; however, because of low ABC and TAC amounts, it is primarily a bycatch-only fishery. They are caught both in bottom trawls and on longlines.

The resource in the BSAI is managed as a single stock. The following information is available to assess the stock condition of Greenland turbot in the BSAI.

<u>Data Component</u>	<u>Years of Data</u>
Trawl survey (size at age)	1975, 1979–1982
Shelf survey (size composition and est. biomass)	1979–1999
Slope survey (size composition and est. biomass)	1979, 1981, 1982, 1985, 1988, 1991
Longline survey (size composition and abundance index)	1983–1993
Total fishery (catch data)	1960–1999
Trawl fishery (catch per unit of effort [CPUE] index)	1978–1984
Trawl fishery (size compositions)	1977–1987, 1989–1991, 1993–1998

Data Component

Longline catch (size composition)

Years of Data

1977, 1979–1985, 1992–1998

The time-series of fishery and survey length compositions allows the use of a length-based stock assessment model (Ianelli et al. 1997). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels, which, when considered with projected future biomass, are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE report.

Greenland turbot are currently managed under Tier 3 of the Council's ABC and OFL definitions (Amendment 44 to the FMP). Management under Tier 3 requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC), and $F_{35\%}$ (for OFL). Since the projected Greenland turbot female spawning biomass for 2000 is greater than $B_{40\%}$ ($165,000 > 81,300$), $F_{40\%}$ is considered the upper limit on ABC. However, the recommended F_{ABC} for 2000 is 25 percent of $F_{40\%}$ due to the lack of recruitment for the past 25 years and the anticipated declining future stock condition.

BSAI 2000 ABC

9,300

BSAI 2000 TAC

9,300

BSAI 1999 Catch

5,776

For information on the Greenland turbot assessment in the GOA, see Section 3.3.1.8.

3.3.1.6 Yellowfin Sole

Yellowfin sole (*Limanda aspera*) is distributed from British Columbia to the Chukchi Sea (Hart 1973). In the Bering Sea, it is the most abundant flatfish species and is the target of the largest flatfish fishery in the United States. While also found in the Aleutian Islands and GOA, the stock is of much smaller size in those areas. Adults are benthic and occupy separate winter and spring/summer spawning and feeding grounds. Adults overwinter near the shelf-slope break at approximately 200 m and move into nearshore spawning areas as the shelf ice recedes (Nichol 1997). Spawning is protracted and variable, beginning as early as May and continuing through August, occurring primarily in shallow water at depths less than 30 m (Wilderbuer et al. 1992). Eggs, larvae and juveniles are pelagic and usually are found in shallow areas (Nichol 1994). The estimated age at 50 percent maturity is 10.5 years at a length of approximately 29 cm (Nichol 1994). The natural mortality rate likely falls within the range of 0.12 to 0.16, with a maximum recorded age of 33 years (Wilderbuer 1997). Yellowfin sole feed primarily on benthic invertebrates, with polychaetes, amphipods, decapods, and clams dominating the diet in the eastern Bering Sea (Livingston 1993).

Yellowfin sole stocks were overexploited by foreign fisheries in 1959–1962. Since that time, indices of relative abundance showed major increases in abundance during the late 1970s, and since 1981, while abundance has fluctuated widely, biomass estimates indicate that the population remains high and stable. Information on yellowfin sole stock conditions in the BSAI comes primarily from the annual eastern Bering Sea trawl survey. Estimates of yellowfin sole biomass derived from these surveys have been more variable than would be expected for a comparatively long-lived and lightly exploited species (Wilderbuer 1997). The reason for this variability is not known. However, Nichol (1997) hypothesized that much of the yellowfin sole resource is found at depths less than 30 m during the summer when bottom trawl surveys are conducted. This could cause the survey to underestimate the abundance of yellowfin sole.

In the Bering Sea, yellowfin sole are considered as one stock for management purposes. The following information is available for stock assessment.

<u>Data Component</u>	<u>Years of Data</u>
Trawl fishery (catch at age)	1964–1998
Trawl survey (population age composition)	1975, 1979–1998
Fishery catch (volume)	1982–1999
Trawl survey (biomass estimates and std. error)	1954–1999
Trawl surveys (maturity schedule)	1992–1993
Trawl surveys (mean weight at age)	1979–1990

The time-series of fishery and survey age compositions allows the use of an age-based stock assessment model (Wilderbuer 1997). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels, which, when considered with projected future biomass, are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE report.

Yellowfin sole are currently managed under Tier 3 of the Council's ABC and OFL definitions (Appendix 1; Amendment 44). Management under Tier 3 requires reliable estimates of projected biomass, $B_{40\%}$, $F_{40\%}$ (for ABC), and $F_{35\%}$ (for OFL). Since the projected yellowfin sole female spawning biomass for 2000 is greater than $B_{40\%}$ ($789,300 > 576,600$), $F_{40\%}$ (the upper limit on ABC), is recommended as the F_{ABC} harvest reference point for 2000.

<u>BSAI 2000 ABC</u>	<u>BSAI 2000 TAC</u>	<u>BSAI 1999 Catch</u>
191,000 mt	123,262 mt	67,392 mt

For information on the GOA yellowfin sole assessment, see Section 3.3.1.8.

3.3.1.7 Arrowtooth Flounder

Arrowtooth flounder is common from Oregon through the eastern Bering Sea (Allen and Smith 1988). The very similar Kamchatka flounder (*Atheresthes evermanni*) also occurs in the Bering Sea. Because it is not usually distinguished from arrowtooth flounder in commercial catches, both species are managed as a group. Arrowtooth flounder is a relatively large flatfish that occupies continental shelf waters almost exclusively until age 4, but at older ages occupies both shelf and slope waters, with concentrations at depths between 100 and 200 m (Martin and Clausen 1995). Spawning is protracted and variable and probably occurs from September through March (Zimmermann 1997). For female arrowtooth flounder collected off the Washington coast, the estimated age at 50 percent maturity was 5 years, with an average length of 37 cm. Males matured at 4 years and 28 cm (Rickey 1995). Values of 50 percent maturity for the Bering Sea stock are 42.2 cm and 46.9 cm for males and females, respectively (Zimmerman 1997). The maximum reported ages are 16 years in the Bering Sea, 18 years in the Aleutian Islands, and 23 years in the GOA, with a natural mortality rate used for assessment purposes of 0.2 (Turnock et al. 1997b, Wilderbuer and Sample 1997).

Arrowtooth flounders are important as a large and abundant predator of other groundfish species. Adults are almost exclusively piscivorous and over half their diet can consist of pollock (Livingston 1991b). Currently, arrowtooth flounder have a low perceived commercial value because the flesh softens soon after capture due

to protease enzyme activity (Greene and Babbitt 1990). Enzyme inhibitors such as beef plasma have been found to counteract this flesh-softening activity, but suitable markets have not been established to support increased harvests. Thus, arrowtooth flounder are primarily caught by bottom trawls as bycatch in other high-value fisheries. Stocks are lightly exploited and appear to be increasing in both the GOA and the BSAI. Information on arrowtooth flounder stock conditions in the BSAI comes primarily from the annual eastern Bering Sea shelf trawl survey. Limited information is also available from past slope surveys (1981–1991) and catch sampling of the commercial fishery.

Information on Bering Sea arrowtooth flounder is available from the following sources:

<u>Data Component</u>	<u>Years of Data</u>
Fishery catch (volume)	1970–1999
Shelf survey (est. biomass and std. error)	1982–1999
Slope survey (est. biomass and std. error)	1981, 1982, 1985, 1988, 1991
Shelf survey (size composition by sex)	1979–1999
Slope survey (size composition by sex)	1981, 1982, 1985, 1988, 1991
Fishery catch (length-frequencies from observers)	1978–1991

The time-series of fishery and survey size compositions allows the use of a size-based stock assessment model (Wilderbuer and Sample 1997). The outputs include estimates of sex-specific abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels, which, when considered with projected future biomass, are used to calculate ABC. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE report.

The reference fishing mortality rate and ABC for arrowtooth flounder are determined by the amount of population information available (Appendix 1; Amendment 44). Arrowtooth flounder are managed under Tier 3 of the ABC/OFL definition since equilibrium recruitment could be approximated by the average recruitment from the time-series estimated in the stock assessment, and $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ could be estimated. In the 1999 assessment, projected $B_{2000} > B_{40\%}$ (496,000 mt > 194,600 mt) allowing the $F_{40\%}$ fishing mortality rate (the upper limit) to be recommended for calculating ABC. The 2000 Council TAC was set equal to the ABC. Increased future harvest is likely constrained by Pacific halibut bycatch limitations.

<u>BSAI 2000 ABC</u>	<u>BSAI 2000 TAC</u>	<u>BSAI 1999 Catch</u>
131,000 mt	131,000 mt	10,679 mt

Information on GOA arrowtooth flounder used for stock assessments is available from the following sources:

<u>Data Component</u>	<u>Years of Data</u>
Fishery catch (volume)	1960 to 1999
International Pacific Halibut Commission (IPHC) trawl (est. survey biomass and std. error)	1961 to 1962
NMFS exploratory research trawl survey (est. biomass and std. error)	1973 to 1976

<u>Data Component</u>	<u>Years of Data</u>
NMFS triennial trawl survey (est. biomass and std. error)	1984, 1987, 1990, 1993, 1996, 1999
Fishery catch(size compositions)	1977 to 1981, 1984 to 1993, 1995 to 1996
NMFS triennial trawl survey (size compositions)	1984, 1987, 1990, 1993, 1996, 1999
NMFS GOA groundfish surveys (length-at-age data)	1975, 1977 to 1978, 1980 to 1983
NMFS triennial trawl survey (length-at-age data)	1984, 1987, 1990, 1993, 1996

Current abundance estimates indicate that arrowtooth flounder have the largest biomass of the groundfish species inhabiting the GOA. The time-series of fishery and survey size compositions allows the use of a size-based stock assessment model (Turnock et al. 1997b). The outputs include estimates of sex-specific abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels, which are used to calculate ABC. The stock assessment is updated annually and incorporated into the GOA SAFE report.

The reference fishing mortality rate and ABC for arrowtooth flounder are determined by the amount of population information available. Assuming that equilibrium recruitment can be approximated by the average recruitment from the time-series estimated in the stock assessment, $B_{40\%}$, $F_{40\%}$, and $F_{30\%}$ are known, and because $B_{2000} > B_{40\%}$ ($1,075,900 > 436,700$), $F_{40\%}$ (the upper limit) is the recommended fishing mortality rate to calculate ABC. The 2000 Council TAC of 35,000 mt is well below the ABC of 145,360 mt recommended from the stock assessment. Increased future harvest is likely constrained by Pacific halibut bycatch limitations.

<u>GOA 2000 ABC</u>	<u>GOA 2000 TAC</u>	<u>GOA 1999 Catch</u>
145,360 mt	35,000 mt	16,062 mt

3.3.1.8 Other Flatfish

In the Bering Sea, eight other flatfish species are managed under the FMPs. Alaska plaice (*Pleuronectes quadriterculatus*), rex sole (*Glyptocephalus zachirus*), Dover sole (*Microstomus pacificus*), starry flounder (*Platichthys stellatus*), English sole (*Parophrys vetulus*), butter sole (*Isopsetta isolepis*), sand sole (*Psettichthys melanostictus*), and deepsea sole (*Embassichthys bathybius*). Adults of all species are benthic and occupy separate winter spawning and summer feeding grounds. Adults overwinter in deeper water and move into nearshore spawning areas in the late winter and spring. Spawning takes place as early as November for Dover sole (Hagerman 1952) but occurs from February through April for most species (Hart 1973). All flatfish eggs are pelagic and sink to the bottom shortly before hatching (Alderdice and Forrester 1968, Hagerman 1952, Orcutt 1950, Zhang 1987), except for butter sole, which has demersal eggs (Levings 1968).

In the Bering Sea, Alaska plaice is the most abundant and commercially important of the other flatfish species. It is a comparatively long-lived species, and has frequently been aged as high as 25 years. For stock assessment purposes, a natural mortality rate of 0.25 is used (Wilderbuer and Walters 1997b). Alaska plaice appear to feed primarily on polychaetes, marine worms, and other benthic invertebrates (Livingston and DeReynier 1996, Livingston et al. 1993). For the other seven species in the BSAI other flatfish management category, little is known of their feeding habits, spawning, growth characteristics, or seasonal movements and population age and size structure.

In general, other flatfish are taken as bycatch in bottom trawl fisheries for other groundfish. Alaska plaice are also taken in directed bottom trawl fisheries in the eastern Bering Sea. Because other flatfish are generally not targeted, commercial catch data is of limited use for stock assessment purposes. The principal source of information for evaluating the condition of other flatfish stocks in the BSAI is the annual eastern Bering Sea shelf trawl survey.

A moderate amount of information is available for Alaska plaice in the Bering Sea and is summarized below.

Data Component	Years of Data
Trawl survey (catch number at age)	1971–1979, 1988, 1995
Trawl survey (total catch weight)	1971–1999
Trawl survey (age-specific estimates of proportion of mature females)	1971–1996
Trawl survey (est. biomass estimates and std. error)	1982–1999
Trawl survey (age composition)	1979, 1981, 1982, 1988, 1992–1995

The time series of fishery and survey age compositions allows the use of an age-based stock assessment model (Spencer et al. 1999). The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model also estimates reference fishing mortality rates in terms of the ratio of female spawning biomass to unfished levels, which, when considered with projected future stock abundance, are used to calculate ABC. For the rest of the species of the other flatfish management group, annual trawl survey biomass estimates are considered the best information available to determine the stock biomass. The stock assessment is updated annually at the conclusion of the summer trawl survey and is incorporated into the BSAI SAFE report. Bering Sea management values are as follows:

<u>BSAI 2000 ABC</u>	<u>BSAI 2000 TAC</u>	<u>BSAI 1999 Catch</u>
117,000 mt	83,813 mt	15,184 mt

The other flatfish species complex in the GOA is currently managed as four categories with separate ABCs: shallow water flatfish, deep water flatfish, flathead sole, and rex sole. The shallow water flatfish consist of Alaska plaice, starry flounder, yellowfin sole, English sole, butter sole, northern rock sole, and southern rock sole. Deep water flatfish are Dover sole, Greenland turbot, and deepsea sole. The shallow water category catch in 1999 was about 60 percent rock sole (southern and northern combined), 15 percent butter sole, 11 percent starry flounder, 4 percent English sole, 4 percent yellowfin sole, less than 1 percent Alaska plaice, and 5 percent sand sole. The deep water catch is practically all Dover sole (over 99 percent in 1999).

The classification into the shallow water and deep water groups was due to significant differences in halibut bycatch rates in directed fisheries targeting on shallow and deep water flatfish species. Flathead sole were assigned a separate ABC due to their overlap in depth distribution of the shallow and deep water groups. In 1993, rex sole was split out of the deep water management category because of concerns regarding the Pacific ocean perch bycatch in the rex sole target fishery. The information available for each species varies.

<u>Data Component</u>	<u>Years of Data</u>
Trawl surveys (age composition, not all species)	Various years

Data Component**Years of Data**

Triennial bottom trawl survey (est. biomass and std. error)	1984, 1987, 1990, 1993, 1996, 1999
Total fishery catch (weight by management category)	Various years
Trawl survey (size composition)	1984, 1987, 1990, 1993, 1996, 1999

Stock assessment models were not used for any species here due to the lack of available information (Turnock et al. 1999b). Triennial trawl survey biomass estimates from 1984, 1987, 1990, 1993, 1996, and 1999 are considered the best information available to determine the stock biomass for all of the other flatfish species.

The reference fishing mortality rate and ABC for the flatfish management groups are determined by the amount of population information available. Rock sole, for which maturity information from Bering sea rock sole is deemed adequate, are in Tier 4 of the ABC and overfishing definitions, where $F_{ABC} = F_{40\%}$ and $F_{OFL} = F_{30\%}$. ABCs for all flatfish except rock sole, deepsea sole, and Greenland turbot were calculated using $F_{ABC} = 0.75$ m and $F_{OFL} = m$ (Tier 5), because maturity information was not available. Natural mortality was assumed to be 0.2 for all flatfish species except Dover sole, for which m is 0.1. Greenland turbot and deepsea sole are in Tier 6 because no reliable biomass estimates exist, where $ABC = 0.75$ OFL and the OFL = the average catch from 1978 to 1995.

The TAC is well below the ABC for shallow water group and flathead sole. The ABC, TAC, and catch are summarized below. The TAC is essentially the same as the ABC for the deep water group and rex sole. The flatfish fishery in the GOA mainly targets rock sole, rex sole, and Dover sole. The flatfish catch is limited by halibut bycatch and does not reach the TAC for any species group.

<u>GOA Management Group</u>	<u>GOA 2000 ABC</u>	<u>GOA 2000 TAC</u>	<u>GOA 1999 Catch</u>
Shallow water	37,860	19,400	2,545
Deep water	5,300	5,300	2,285
Flathead sole	26,270	9,060	891
Rex sole	9,440	9,440	3,057

3.3.1.9 Sablefish

Sablefish (*Anoploma fimbria*) are found from northern Mexico to the GOA, westward to the Aleutian Islands, and in gullies and deep fjords generally at depths greater than 200 m. Sablefish observed from a manned submersible were found on or within 1 m of the bottom (Krieger 1997). Studies have shown sablefish to be highly migratory for at least part of their life cycle (Heifetz and Fujioka 1991, Maloney and Heifetz 1997), and substantial movement between the BSAI and the GOA has been documented (Heifetz and Fujioka 1991). Thus sablefish in Alaskan waters are assessed as a single stock (Sigler et al. 1999). Adults reach maturity at 4 to 5 years and a length of 51 to 54 cm (McFarlane and Beamish 1990). Spawning is pelagic at depths of 300–500 m near the edges of the continental slope (McFarlane and Nagata 1988). Juveniles are pelagic and appear to move into comparatively shallow nearshore areas where they spend the first 1 to 2 years (Rutecki and Varosi 1997). Sablefish are long-lived, with a maximum recorded age in Alaska of 62 years (Sigler et al. 1997). For stock assessments, a natural mortality rate of about 0.10 has been estimated (Sigler et al. 1999). It appears that sablefish are opportunistic feeders. Feeding studies conducted in Oregon and California found that fish made up 76 percent of the diet (Laidig et al. 1997). Other studies, however, have found a diet dominated by euphausiids (Tanasichuk 1997).

Alaskan sablefish are considered a single stock and assessed in a combined area (BSAI and GOA) with an age-structured model incorporating fishery and survey catch data and age and length compositions. Survey data come from annual sablefish longline surveys in the GOA, and biennial longline surveys in the BSAI. These surveys indicate that the stock size peaked in the mid-1980s because of a series of strong years and has declined to lower levels ever since.

The stock assessment includes catch history, fishery description, assessment methods, abundance and exploitation trends, and projected catch and abundance. Sablefish fall into Tier 3 of the ABC and OFL definitions, which requires reliable estimates of biomass, $B_{40\%}$, $F_{35\%}$, and $F_{40\%}$. Under the definitions and projected stock conditions in 1999, the overfishing fishing mortality rate was the adjusted $F_{35\%}$ rate, which was 0.136 for sablefish and equated to a combined stock yield of 21,400 mt. Projections for 2000 showed that the maximum allowable fishing mortality rate for ABC (F_{ABC}) was the adjusted $F_{40\%}$ rate (0.109), which translated to a combined stock yield of 17,300 mt. The 2000 ABC recommendation was set at the adjusted $F_{40\%}$ rate. The stock assessment authors also constructed an approximate probability figure on the odds of the year 2004 spawning biomass dropping below the projected year 2000 level. They determined that a constant 5-year catch scenario of 17,000 mt was appropriate for minimizing the risks of further stock declines.

Recent important year classes are 1997, 1995, and 1990, although the abundance estimate for the 1997 cohort is uncertain because it is based on only one year of data. Abundance has fallen in recent years because recent recruitment is insufficient to replace strong year classes from the later 1970s, which are dying off. The estimated mean age of the recruited portion of the population is 7.3 years. The dominating factor determining the age composition is the magnitude of the recruiting year classes. The selectivity of the fishery has cumulative impacts on the age composition due to fishing mortality, and the current composition is also the result of a fished population with a several-decades catch history. How the current age composition of the population compares with the unfished population is unknown.

The directed fishery for sablefish is conducted by longliners. Trawlers also catch sablefish as bycatch in other fisheries. A tiny amount of sablefish is caught by pot boats. By gear, the catches in 1998 were longlines (90 percent), trawls (10 percent), and pots (less than 1 percent). The directed fishery occurs on the upper continental slope and a few deep water gullies, the areas inhabited by adult sablefish. The average discard from 1994 to 1997 was 3 percent for all longline fisheries and 27 percent for all trawl fisheries.

Larval sablefish feed on a variety of small zooplankton, ranging from copepod nauplii to small amphipods. The epipelagic juveniles feed primarily on macrozooplankton and micronekton (i.e., euphausiids). The older demersal juveniles and adults appear to be opportunistic feeders, with food ranging from variety of benthic invertebrates, benthic fishes, as well as squid, mesopelagic fishes, jellyfish, and fishery discards. Gadid fish (mainly pollock) comprise a large part of the sablefish diet. Nearshore residence during their second year provides the opportunity to feed on salmon fry and smolts during the summer months. Young-of-the-year sablefish are commonly found in the stomachs of salmon taken in the southeast Alaska troll fishery during the late summer.

3.3.1.10 Rockfish

At least 32 rockfish species of the genera *Sebastes* and *Sebastolobus* have been reported to occur in the GOA and BSAI (Eschmeyer et al. 1984), and several of them are of commercial importance. Pacific ocean perch (*Sebastes alutus*) has historically been the most abundant rockfish species in the region and has contributed most to the commercial rockfish catch. Other species such as northern rockfish (*S. polyspinis*), rougheye rockfish (*S. aleutianus*), shortraker rockfish (*S. borealis*), shortspine thornyheads (*Sebastolobus alascanus*), yelloweye rockfish (*Sebastes ruberrimus*), and dusky rockfish (*S. ciliatus*) are also important to the overall

rockfish catches. The TAC levels for these and all other rockfish species are determined by the Council on an annual basis. Among the main inputs needed for making this determination are the ABC and OFL recommendations from annual stock assessments conducted for each species and/or species assemblage.

Rockfish in the GOA are currently managed as four assemblages: (1) slope rockfish, (2) pelagic shelf rockfish, (3) demersal shelf rockfish, and (4) thornyheads. Separate ABCs, OFLs, and TACs are set for each assemblage, except for slope rockfish, which is further subdivided into four subgroups with separate ABCs, OFLs, and TACs: (1) Pacific ocean perch, (2) shortraker and rougheye rockfish, (3) northern rockfish, and (4) other slope rockfish.

Rockfish in the BSAI are currently managed as two assemblages: (1) Pacific ocean perch complex and (2) other rockfish. The Pacific ocean perch complex includes Pacific ocean perch, rougheye rockfish, shortraker rockfish, sharpchin rockfish, and northern rockfish. For the eastern Bering Sea region, the Pacific ocean perch complex is divided into two subgroups with (1) Pacific ocean perch and (2) shortraker, rougheye, sharpchin, and northern rockfish combined. For the Aleutian Islands, the Pacific ocean perch complex is divided into three subgroups: (1) Pacific ocean perch, (2) shortraker and rougheye rockfish, and (3) sharpchin and northern rockfish. Separate ABCs, TACs, and OFLs are assigned to each subgroup. Other rockfish includes all *Sebastes* and *Sebastolobus* species in the BSAI other than the Pacific ocean perch complex. Shortspine thornyheads account for more than 90 percent of the estimated biomass of the other rockfish assemblage in the BSAI.

Rockfish are assessed with either an age-structured model or trawl-survey-based model, depending on the management group. Pacific ocean perch are assessed with an age-structured model incorporating fishery and survey catch and age composition data. Most other rockfish species are assessed based on trawl survey catch data. Survey data are from the NMFS triennial trawl surveys. The stock assessments provide the best available information. For all rockfish management groups, the assessment includes catch history, characterizations of the fishery, assessment methodology, and abundance and exploitation trends. The results of the analyses, which are updated annually, are presented in the GOA and BSAI stock assessment report, which is incorporated into the Council's SAFE reports.

Pacific Ocean Perch

Pacific ocean perch is primarily a demersal species that inhabits the outer continental shelf and slope regions of the North Pacific Ocean and the Bering Sea from southern California to Japan (Allen and Smith 1988). As adults, they live on or near the seafloor, generally in areas with smooth bottoms (Krieger 1993) and generally at depths ranging from 180 to 420 m. The diet of Pacific ocean perch appears to consist primarily of plankton (Brodeur and Percy 1984); euphausiids are the single most important prey item (Yang 1996).

Though more is known about the life history of Pacific ocean perch than about other rockfish species (Kendall and Lenarz 1986), much uncertainty still exists about its life history. Pacific ocean perch are viviparous, with internal fertilization and the release of live young (Hart 1973). Insemination occurs in the fall, and release of larvae occurs in April or May. Pacific ocean perch larvae are thought to be pelagic and drift with the current. Juveniles seem to inhabit rockier, higher relief areas than adults (Carlson and Straty 1981, Krieger 1993). Pacific ocean perch is a slow-growing species that, in the GOA, reaches maturity at approximately 10 years, or 36 cm in length (Heifetz et al. 1997) and has a maximum life span of 90 years (Chilton and Beamish 1982). The natural mortality rate likely is between 0.02 and 0.08 (Archibald et al. 1981, Chilton and Beamish 1982).

Pacific ocean perch is the most commercially important rockfish in Alaska's fisheries and is taken mostly with bottom trawls. The species supported large Japanese and Soviet trawl fisheries throughout the 1960s and is

highly valued. Apparently, stocks were not productive enough to support the large removals that took place, and they declined throughout the 1960s and 1970s, reaching their lowest levels in the early 1980s. Since that time, stocks have stabilized in the eastern Bering Sea, and increased in the Aleutian Islands and GOA.

A time-series of fishery and survey age compositions allows the use of an age-based stock assessment model for Pacific ocean perch. The outputs include estimates of abundance, spawning biomass, fishery and survey selectivity, exploitation trends, and projections of future biomass. The model uses the ratio of female spawning biomass to that which would exist without fishing to estimate reference fishing mortality rates. The reference fishing mortality rates are used to calculate ABC, and the assessment is updated annually.

In the GOA, Pacific ocean perch fall into Tier 3 of the ABC and OFL definitions, which requires reliable estimates of biomass, $B_{40\%}$, $F_{30\%}$, and $F_{40\%}$. Under the definitions and current stock conditions, the OFL fishing mortality rate for Pacific ocean perch is the $F_{35\%}$ adjusted rate, which is 0.078 for Pacific ocean perch and equates to a yield of 15,385 mt. The maximum allowable fishing mortality rate for ABC (F_{ABC}) defined by Tier 3 is the $F_{40\%}$ adjusted rate, which is 0.065 for Pacific ocean perch and translates to a yield of 13,020 mt. The stock assessment fishing mortality rate for ABC is equivalent to the maximum allowable fishing mortality rate. The 2000 Council TAC level is 13,020, equal to the recommended stock assessment ABC.

The age and size distributions of Pacific ocean perch in the GOA are discussed in Heifetz et al. (1999). Information is available from the 1984, 1987, 1990, 1993, and 1996 surveys. The dominating factor determining age composition is the magnitude of the recruiting year classes which are highly variable. The first three surveys show a strong 1976 year-class, and the 1980 year-class appears strong in the 1987 survey and average in the 1990 survey. The 1986 year-class appears strong in the 1990 survey, and exceptionally strong in the 1993 and 1996 surveys. The selectivity of the fishery has cumulative impacts on the age composition due to fishing mortality, and it is not certain how the current age composition of the population would compare to an unfished population.

In the GOA, the directed fishery for Pacific ocean perch is conducted by catcher-processors and catcher bottom trawlers. The percentage of Pacific ocean perch taken by pelagic trawls has increased from 2 to 8 percent during 1990–1995 and from 14 to 20 percent during 1996–1998. Factory trawlers continue to take nearly all the catch in the eastern and western GOA; however, since 1996, the percentage of Pacific ocean perch in the central GOA taken by shore-based trawlers has ranged from 28 percent to 49 percent. The fishery generally occurs at depths between 150 m and 300 m along the outer continental shelf, the upper continental slope and at the mouth of gullies. Important Pacific ocean perch fishery locations include, in the eastern GOA, the gully and slope southwest of Yakutat Bay and off Cape Omaney; in the central GOA, the shelf, slope, and gullies off of Kodiak Island south of Portlock Bank and near Albatross Bank; and in the western GOA, the shelf and slope south of Unimak and Umnak Islands.

In the GOA, Pacific ocean perch are caught as bycatch (not necessarily discarded) in other directed fisheries aimed mostly at other rockfish species. Heifetz and Ackley (1997) analyzed bycatch in rockfish fisheries of the GOA. Bycatch rates of Pacific ocean perch are highest in the pelagic shelf rockfish, other slope rockfish, and shortspine thornyhead fisheries. Information on bycatch in non-rockfish fisheries has not been analyzed. Recent discard rates (discards divided by total catch) of Pacific ocean perch have been about 15 percent (Heifetz et al. 1997). In 1997, about 1,360 mt of Pacific ocean perch were discarded, compared to a total catch of 9,500 mt.

During the summer of 1990, the diets of commercially important groundfish species in the GOA were analyzed by Yang (1993). About 98 percent of the total stomach content weight of Pacific ocean perch in the study was made up of invertebrates and 2 percent of fish. Euphausiids (mainly *Thysanoessa inermis*) were the most

important prey item. Euphausiids comprised 87 percent, by weight, of the total stomach contents. Calanoid copepods, amphipods, arrow worms, and shrimp were frequently eaten by Pacific ocean perch. Documented predators of Pacific ocean perch include Pacific halibut and sablefish, and it is likely that Pacific cod and arrowtooth flounder also prey on Pacific ocean perch. Pelagic juveniles are consumed by salmon, and benthic juveniles are eaten by lingcod and other demersal fish (NMFS 1997b).

In the BSAI, Pacific ocean perch are assessed with an age-structured model incorporating fishery and survey catch data and age compositions. Survey data are from the NMFS triennial trawl groundfish surveys and the fishery data comes from the observer program. The stock assessment is based on the best available information. It includes catch history, characterizations of the fishery, assessment methodology, abundance and exploitation trends, and projected catch and abundance trends for a range of fishing mortalities and recruitment assumptions (Ito et al. 1999). The assessments for the other species in the Pacific ocean perch complex and for the “other rockfish” management category are based on substantially less information (Ito and Spencer 1999, Ito et al. 1999).

The current spawning biomass for Pacific ocean perch in the Aleutian Islands is about 2,500 mt below its long-term average under an $F_{40\%}$ ($= 0.072$) harvest strategy. The current estimate of spawning biomass for this stock is about 97,800 mt, whereas the long-term equilibrium spawning biomass is about 100,300 mt. Based on the guidelines established under Tier 3, the adjusted F_{ABC} was calculated as 0.0702, which equates to an ABC estimate of approximately 12,300 mt. The total Aleutian Islands recommended ABC was then apportioned among Aleutian Islands subareas based on survey distribution, as follows: western Aleutian Islands = 5,670 mt, central Aleutian Islands = 3,510 mt, and eastern Aleutian Islands = 3,120 mt. This was done to better distribute fishing effort over a wider area, thereby reducing the chance for localized depletion. The OFL was determined using an adjusted $F_{35\%}$ rate of 0.0826, which translates to an OFL of 14,400 mt.

For the eastern Bering Sea stock of Pacific ocean perch, the estimate of current spawning biomass is also below its long-term average. The current estimate of spawning biomass for this stock is about 24,900 mt, and its long-term equilibrium spawning biomass is 26,200 mt. The same adjustment procedure used for the Aleutian Islands $F_{40\%}$ rate was also applied to the eastern Bering Sea $F_{40\%}$ estimate. This procedure produced an F_{ABC} of 0.0544 and an ABC estimate for the eastern Bering Sea of approximately 2,600 mt. The overfishing mortality level (F_{OFL}) was given as an adjusted $F_{35\%}$ and was 0.0653, which translates to an OFL of about 3,100 mt.

Shortraker and Roughey Rockfish

Shortraker (*Sebastes borealis*) and roughey rockfish (*S. Aleutianus*) inhabit the outer continental shelf of the North Pacific Ocean from the eastern Bering Sea as far south as Southern California (Kramer and O'Connell 1988). Adults of both species are semidemersal and are usually found in deeper waters (from 50 m to 800 m) and over rougher bottoms than Pacific ocean perch (Krieger and Ito 1999). Little is known about the biology and life history of these species, but they appear to be long-lived, with late maturation and slow growth. Shortraker rockfish have been estimated to reach ages in excess of 120 years and roughey rockfish in excess of 140 years. Natural mortality rates have been estimated by Heifetz and Clausen (1991) at 0.025 for roughey rockfish and 0.030 for shortraker rockfish. Like other members of the genus *Sebastes*, they are viviparous (bear live young), and birth occurs in the early spring through summer (McDermott 1994). Food habit studies conducted by Yang (1993) indicate that the diet of roughey rockfish is dominated by shrimp. The diet of shortraker rockfish is not well known; however, based on a small number of samples, the diet appears to be dominated by squid. Because shortraker rockfish have large mouths and short gill rakers, it is possible that they are potential predators of other fish species (Yang 1993). Though shortraker and roughey rockfish are highly valued, amounts available to the commercial fisheries are limited by relatively small TAC and ABC

amounts, which are to support bycatch needs in other groundfish fisheries. As a result, the directed fishery for these species is typically closed at the beginning of the fishing year.

The primary methods of harvest for shortraker and rougheye rockfishes are bottom trawls and longline gear. The bulk of the commercial harvest usually occurs at depths between 200 m and 500 m along the upper continental slope. Both species are associated with a variety of habitats, from soft to rocky bottoms, although boulders and sloping terrain appear also to be desirable habitat. Age at recruitment is uncertain, but is probably on the order of 20+ years for both species. Length at 50 percent sexual maturity is about 45 cm for shortraker rockfish and about 44 cm for rougheye rockfish (McDermott 1994).

A sufficient time series of fishery and survey age compositions is not available to construct an age-based stock assessment model for shortraker and rougheye rockfish. Thus, assessment is based mostly on exploitable biomass estimates provided by NMFS trawl surveys. Specifically, exploitable biomass for the GOA stocks is estimated as the unweighted average of the three most recent surveys (1993, 1996, and 1999), excluding the 1–100 m depth stratum (which contains largely unexploitable juvenile fish). Life history information allows estimates of reference fishing mortality rates, which are used to calculate ABC. The stock assessment is updated annually.

In the GOA, shortraker rockfish falls into Tier 5 and rougheye rockfish into Tier 4 of the ABC and OFL definitions. Under these definitions, the overfishing fishing mortality rate for shortraker rockfish is the $F = M$ rate of 0.03. The maximum allowable fishing mortality rate for ABC (F_{ABC}) defined by Tier 5 for shortraker rockfish is the $F = 0.75M$ rate which is 0.023. The maximum allowable fishing mortality rate for ABC (F_{ABC}) for rougheye rockfish defined by Tier 4 is $F_{40\%}$, which is 0.032. The stock assessment F_{ABC} for rougheye is set equal to the natural mortality M of 0.025, which is lower than the maximum allowable fishing mortality rate for ABC. This results in the recommended ABC of 1,730 mt for shortraker and rougheye rockfish, and this level was adopted as the ABC and TAC by the Council. The shortraker and rougheye rockfish ABC and TAC being set more conservatively than the maximum prescribed under the definitions results in less risk of the F_{ABC} rate being an overly aggressive harvest rate for shortraker and rougheye rockfish. This affords more protection to the stocks, given the variability and uncertainty associated with the abundance.

For the Aleutian Islands shortraker and rougheye rockfish stocks, the assessment is also based on catch and survey data. The biomass estimates from U.S. domestic Aleutian Islands bottom trawl surveys (1991, 1994, and 1997) are averaged to obtain the best estimate of biomass for the species in this subcomplex; earlier U.S.-Japan cooperative surveys were excluded because of differences in survey gear. The 2000 biomass estimates of rougheye and shortraker rockfish were 12,762 mt and 28,713 mt, respectively. In 1996, the Science and Statistical Committee (SSC) to the Council determined that reliable estimates of the natural mortality rate (M) existed for the species in this subcomplex, and that shortraker and rougheye rockfish in the Aleutian Islands therefore qualified for management under Tier 5 (Appendix 1; Amendment 44). The accepted estimates of M are 0.025 for rougheye rockfish and 0.030 for shortraker rockfish. The plan team recommends setting F_{ABC} at the maximum value allowable under Tier 5, which is 75 percent of M . This produced F_{ABC} of 0.019 for rougheye rockfish and 0.023 for shortraker rockfish. Multiplying these rates by the biomass estimates and summing across species gives a 2000 ABC of 885 mt. The plan team's OFL was determined from the Tier 5 formula, where setting $F_{OFL} = M$ for each species gives a combined OFL of 1,180 mt.

In recent years a directed fishery for shortraker and rougheye rockfish has not been allowed because TACs are small. Shortraker and rougheye rockfishes are often caught as bycatch and retained in the sablefish and halibut longline fisheries and fisheries targeting other rockfish species. Heifetz and Ackley (1997) analyzed bycatch (not necessarily discarded) in GOA rockfish fisheries. Bycatch rates of shortraker and rougheye rockfish are highest in the shortspine thornyhead and Pacific ocean perch fisheries. An analysis of bycatch rates in non-

rockfish fisheries has not been conducted. Discard rates (discards divided by total catch) of shortraker and rougheye rockfish in the GOA during 1995 to 1999 ranged from 22 percent to 32 percent (Heifetz et al. 1999). In 1999, about 397 mt of shortraker and rougheye rockfish were discarded compared to a total catch of 1,310 mt.

Northern Rockfish

Northern rockfish (*Sebastes polyspinis*) inhabit the outer continental shelf from the eastern Bering Sea, throughout the Aleutian Islands and the GOA (Kramer and O'Connell 1988). This species is semidemersal and is usually found in comparatively shallower waters off the outer continental slope (from 50–600 m). Little is known about the biology and life history of northern rockfish. However, they appear to be long-lived, with late maturation and slow growth. Heifetz and Clausen (1991) estimated the natural mortality rate for northern rockfish to be 0.060. Like other members of the genus *Sebastes*, they bear live young, and birth occurs in the early spring through summer (McDermott 1994). Food habit studies conducted by Yang (1993) indicate that the diet of northern rockfish is dominated by euphausiids. Although northern rockfish are lower in value than Pacific ocean perch, they still support a valuable directed trawl fishery, especially in the GOA.

In the GOA, northern rockfish falls into Tier 4 of the ABC and OFL definitions. The exploitable biomass (excluding the 1–100-m stratum) is estimated as the weighted mean from the three most recent surveys; this produces an estimate of 85,357 mt for northern rockfish. The maximum allowable fishing mortality rate for ABC (F_{ABC}) defined by Tier 4 is the $F_{40\%}$ rate of 0.075. The stock assessment F_{ABC} for rougheye was set equal to the natural mortality M of 0.06, which is lower than the maximum allowable fishing mortality rate for ABC. This results in the stock assessment ABC of 5,120 mt for northern rockfish. The current Council ABC and TAC levels are 4,990 mt. The northern rockfish ABC and TAC being set more conservatively than the maximum prescribed under the definitions results in less risk of the F_{ABC} rate being an overly aggressive harvest rate for this species. This affords more protection to the stocks, given the variability and uncertainty associated with abundance.

Age-structured information exists for GOA northern rockfish, and has led to the development of an age-structured population model (Heifetz et al. 1999). It is expected that this model will be used for future assessments. The current age and size distributions of Pacific ocean perch in the GOA are discussed in Heifetz et al. (1999). Information is available from the 1984, 1987, 1990, 1993, and 1996 surveys. The dominating factor determining the age composition is the magnitude of the recruiting year classes which are highly variable. Most surveys (except the 1993 survey) indicate that 1968–1971 and 1975–1977 were periods of strong year-classes. The 1993 and 1996 surveys indicate that the 1984 and 1985 year-classes may be stronger than average. The selectivity of the fishery has cumulative impacts on age composition due to fishing mortality, and it is not certain how the current age composition of the population would compare to an unfished population.

The directed fishery for northern rockfish is prosecuted by catcher/processors and catcher bottom trawlers. As with the Pacific ocean perch fishery, a higher percentage of the catch in the central GOA is being taken by shorebased trawlers, ranging from 32 percent to 53 percent from 1996 to 1999. The patterns of the fishery generally reflect the species distribution. The fishery is concentrated at discrete, relatively shallow offshore banks of the outer continental shelf at depths between 75 m and 125 m. Important northern rockfish fishery locations include Portlock Bank and Albatross Bank south of Kodiak Island, Shumagin Bank south of the Shumagin Islands, and Davidson Bank south of Unimak Island.

Heifetz and Ackley (1997) analyzed bycatch (not necessarily discarded) in GOA rockfish fisheries. Bycatch rates of northern rockfish are highest in the pelagic shelf rockfish, other slope rockfish, and Pacific ocean perch fisheries. Information on bycatch of northern rockfish in non-rockfish fisheries has not been analyzed. Discard

rates (discards divided by total catch) of the GOA northern rockfish from 1995 to 1999 ranged from 13 percent to 28 percent (Heifetz et al. 1999). In 1999, about 597 mt of northern rockfish were discarded compared to a total catch of 5,297 mt.

Northern rockfish are generally planktivorous (feed on plankton) with euphausiids being the predominant prey item (Yang 1993). Copepods, hermit crabs, and shrimp have also been noted as prey items in much smaller quantities. Predators of northern rockfish are not well documented, but likely include larger fish such as Pacific halibut that are known to prey on other rockfish species.

In the Aleutian Islands, northern rockfish are managed together with sharpchin rockfish (*S. zacentrus*). Because sharpchin rockfish are only rarely found in the Aleutian Islands, northern rockfish are, for all practical purposes, the only species in this subcomplex. As with the shortraker and rougheye stocks, the biomass estimates from U.S. domestic Aleutian Islands bottom trawl surveys (1991, 1994, and 1997) are averaged to obtain the best estimate of biomass for the species in this subcomplex. This procedure produced a biomass estimate of 114,501 mt. Northern rockfish in the Aleutian Islands are managed under Tier 5 of Amendment 44. The accepted estimate of M for northern rockfish in the Aleutian Islands is 0.06. ABC was based on maximum allowable F_{ABC} under Tier 5, which is 75 percent of M , or 0.045. Multiplying this rate by the best estimate of biomass gave a 2000 ABC of 5,153 mt. The plan team's OFL was determined from the Tier 5 formula, which set $F_{OFL} = M$ giving a 2000 OFL of 6,870 mt.

Pelagic Shelf Rockfish

In the GOA, pelagic shelf rockfish consist of dusky rockfish (*Sebastes ciliatus*), yellowtail rockfish (*S. flavidus*), and widow rockfish (*S. entomelys*). Black rockfish were formerly in this group, but were removed in April, 1998, from both the pelagic shelf group and the GOA groundfish FMP. Dusky rockfish is by far the most important species in the group, both in terms of abundance and commercial value. This complex is assessed with a trawl-survey-based model, with survey data coming from the NMFS GOA triennial trawl surveys. The stock assessments provide the best available information for pelagic shelf rockfish, and include discussions of catch history, characterizations of the fishery, assessment methodology, and abundance and exploitation trends. The results of the analyses, which are updated annually, are presented in the GOA pelagic shelf rockfish stock assessment, which is incorporated into the GOA SAFE report.

Pelagic shelf rockfish fall into Tier 4 of the current ABC/OFL definitions, which requires estimates of biomass, $F_{35\%}$ and $F_{40\%}$. Biomass estimates are produced from averaging the three most recent triennial surveys (1993, 1996, and 1999), and the current exploitable biomass is 66,443 mt. Estimates of $F_{35\%}$ and $F_{40\%}$ are derived using life history parameters for dusky rockfish. According to the definitions for Tier 4, the maximum allowable fishing mortality rate for ABC (F_{ABC}) is the $F_{40\%}$ rate, which is 0.11 for pelagic shelf rockfish and translates to a gulfwide yield of 7,309 mt. The actual stock assessment F_{ABC} for pelagic shelf rockfish, however, is set to a more conservative value, $F = M$, in which F_{ABC} equals the natural mortality of dusky rockfish, 0.090. Hence, the corresponding yield is 5,980 mt, which is the recommended ABC value in the stock assessment for 2000. The Council has adopted this level for both the ABC and TAC for 2000. The corresponding OFL fishing mortality rate is $F_{35\%} = 0.136$, which results in an OFL yield of 9,036 mt. The northern rockfish ABC and TAC being set more conservatively than the maximum prescribed under the definitions results in less risk of the F_{ABC} rate being an overly aggressive harvest rate for this species. This affords more protection to the stocks, given the variability and uncertainty associated with abundance.

Age and size distributions of dusky rockfish are based on results of the five triennial trawl surveys from 1984 to 1996, and are discussed in Clausen and Heifetz (1999). Age results are only available from the 1987, 1990, and 1993 surveys, and these show that substantial recruitment of dusky rockfish appears to be a relatively

infrequent event. Strong year classes are only seen for 1976–1977, 1979–1980, and 1986. The size compositions from each of the five surveys indicate that recruitment of small fish to the survey occurred only in 1993, corresponding to the 1986 year class. The effects of fishing on the age and size compositions are unknown, as no age or size data are available from either the fishery, or from the unfished population prior to the beginning of the fishery.

Dusky rockfish are caught almost exclusively with bottom trawls. Factory trawlers dominated the directed fishery from 1988 to 1995. Since 1996, the percentage of the catch taken by shore-based trawlers in the central GOA has ranged from 18 to 45 percent. Catches are concentrated at a number of relatively shallow, offshore banks of the outer continental shelf, especially the W grounds west of Yakutat and Portlock Bank (NMFS 1997b). Other fishing grounds include Albatross Bank, the “Snakehead” south of Kodiak Island, and Shumagin Bank. Highest catch per unit effort is generally taken at depths of 10–150 m (Reuter 1999).

Dusky rockfish often co-occur with northern rockfish, and they are caught as bycatch in the northern rockfish and other slope rockfish fisheries (Heifetz and Ackley 1997). To a lesser extent, they are also taken as bycatch in the Pacific ocean perch fishery. Overall discard rates (discards divided by total catch) of dusky rockfish in recent years have been quite low, generally 10 percent or less (Clausen and Heifetz 1999).

Trophic interactions of dusky rockfish are not well known. Food habits information is available from just one study, with a relatively small sample size for dusky rockfish (Yang 1993). This study indicated that adult dusky rockfish consume primarily euphausiids, followed by larvaceans, cephalopods, and pandalid shrimp. Predators of dusky rockfish have not been documented, but likely include species that are known to consume rockfish in Alaska, such as Pacific halibut, sablefish, Pacific cod, and arrowtooth flounder.

Demersal Shelf Rockfish

Demersal shelf rockfish include seven species of nearshore, bottom-dwelling rockfish: canary rockfish (*Sebastes pinniger*), China rockfish (*S. nebulosus*), copper rockfish (*S. caurinus*), quillback rockfish (*S. maliger*), rosethorn rockfish (*S. helvomaculatus*), tiger rockfish (*S. nigrocinctus*), and yelloweye rockfish (*S. ruberrimus*). Demersal shelf rockfish are managed by the Council as a distinct assemblage only off the Southeast Outside District (SEO) east of 140°W, an area that is further divided into four management units along the outer coast: the south SEO (SSEO), central SEO (CSEO), north SEO (NSEO), and East Yakutat (EYKT). Yelloweye rockfish comprise 90 percent of the catch and will be the focus of this section.

Yelloweye rockfish occur on the continental shelf from northern Baja California to the eastern Bering Sea, commonly in depths less than 200 m (Kramer and O’Connell 1988). They are long-lived, slow growing, and late maturing. Yelloweye have been estimated to reach an age of 118 years and their natural mortality rate is estimated at 0.20 (O’Connell and Funk 1987). They are viviparous (live bearing) with parturition (birth) occurring primarily in late spring through midsummer (O’Connell 1987). Yelloweye inhabit areas of rugged, rocky relief and adults appear to prefer complex bottoms with the presence of “refuge spaces” (O’Connell and Carlile 1993). Demersal shelf rockfish are highly valued, and a directed longline fishery is held for these species. However, yelloweye are the primary bycatch in the halibut fishery, and therefore a large portion of the TAC and ABC are set aside for bycatch. In 1998, 31 percent of the total demersal shelf rockfish landings occurred as bycatch in the halibut fishery (O’Connell et al. 1999).

Traditional abundance estimation methods (e.g., area-swept trawl surveys, mark recapture) are not considered useful for these fishes, given their distribution, life history, and physiology. However, the Alaska Department of Fish and Game (ADF&G) is continuing research to develop and improve a stock assessment approach for them. As part of that research, a manned submersible, R/V *Delta*, has been used to conduct line transects

(Burnham et al. 1980). Density estimates are limited to adult yelloweye, because it is the principal species targeted and caught in the fishery; therefore, ABC and TAC recommendations for the entire assemblage are keyed to adult yelloweye abundance. Total yelloweye rockfish biomass is estimated for each management subdistrict as the product of density, mean weight of adult yelloweye, and areal estimates of demersal shelf rockfish habitat (O'Connell and Carlile 1993). To estimate yelloweye biomass variability, log-based confidence limits are used, because the distribution of density tends to be positively skewed and density is assumed to be log-normal (Buckland et al. 1993). Both transect line lengths and total area of rocky habitat are difficult to estimate, resulting in some uncertainty in the biomass estimates. Density estimates were made in the EYKT and SSEO in 1999. Density in the SSEO increased 38 percent from the previous density estimate, made in 1994, although some of this change may be due to increased sample size and a change in survey techniques. In contrast, EYKT density decreased 44 percent from the previous estimate, in 1997. During the 1997 survey, the estimate of rocky habitat area in the EYKT was reduced by 60 percent compared to past assessments, resulting in a reduction in the biomass estimate for this area. The sum of the lower 90 percent confidence limits of biomass, by area, is the reference number for setting ABC because of the continued uncertainty in yelloweye biomass estimation. This resulted in a biomass estimate of 15,100 mt for 2000.

Demersal shelf rockfish falls into Tier 4 of the ABC and OFL definitions. Under these definitions, the OFL mortality rate is $F_{35\%} = 0.028$ (420 mt), and the maximum allowable fishing mortality rate for ABC is $F_{40\%} = 0.025$. However, a more conservative approach has been taken for setting ABC and TAC. By applying $F = M = 0.02$ to yelloweye rockfish biomass, and adjusting for the 10 percent of other demersal shelf rockfish species, the recommended 2000 ABC is 340 mt. Continued conservatism in managing this fishery is warranted given the life history of the species and the uncertainty of the biomass estimates.

The age and size distributions of yelloweye rockfish are discussed in O'Connell et al. (1999) and O'Connell and Funk (1987). Estimated length and age at 50 percent maturity for yelloweye collected in the CSEO in 1988 are 45 cm and 21 years for females and 50 cm and 23 years for males. Age of first recruitment into the fishery is between 13 and 18 years. The most recent age data is from the 1998 commercial catch samples. In the CSEO, the area with the longest catch history, the 1997 distribution shows a strong mode at 28 years of age, with some younger modes. The older ages have declined in frequency over time and the average age continues to decline and remains the lowest of all areas. In the SSEO, the 1997 age data shows pronounced modes at 16 and 20 years, with the older ages contributing less. In the EYKT, the 1998 age distribution is multimodal, the largest mode is at 29–30 years, and smaller modes are at 33 and 40 years. Unlike other areas, no sign of recruitment is seen here. The effects of fishing on age and size compositions are unknown, because no age or size data are available from either the fishery or the unfished population prior to the beginning of the fishery.

The directed fishery for demersal shelf rockfish is conducted by longliners. Yelloweye rockfish occur in areas of rugged, rocky bottom, commonly between 100 and 200 m. The lava fields off Cape Edgecumbe in the CSEO and the offshore Fairweather Ground in the EYKT are the most important fishing areas. A small amount of demersal shelf rockfish are taken as bycatch in jig and troll fisheries. Trawling is prohibited in the eastern GOA. Yelloweye rockfish is the dominant bycatch species in the halibut longline fishery. The majority of the longline vessels in the eastern GOA are unobserved so it is difficult to get an accurate accounting of discards at sea. For the past several years unreported mortality of demersal shelf rockfish during the halibut fishery were estimated, based on IPHC interview data. The 1993 interview data indicates a total mortality of demersal shelf rockfish of 13 percent (by weight) of the June halibut landings and 18 percent of the September halibut landings. Unreported mortality data have been more difficult to collect under the halibut IFQ fishery and appear to be less reliable than previous data. The allowable bycatch limit of demersal shelf rockfish during halibut fishing is 10 percent of the halibut weight. The total bycatch of demersal shelf rockfish during the 1999 halibut fishery in the eastern GOA is estimated to be 184 mt, much of which is unreported. Catch statistics do not accurately reflect true mortality of demersal shelf rockfish.

Yelloweye are large, predatory fishes that usually feed close to the bottom. Food habit studies indicate that the diet of yelloweye rockfish is dominated by fish remains, which comprised 95 percent, by volume, of the stomachs analyzed. Herring, sand lance, and Puget Sound rockfish (*S. empheaus*) were particularly dominant. Shrimp are also an important prey item (Rosenthal et al. 1988).

Thornyheads

Thornyheads in Alaskan waters are comprised of two species, the shortspine thornyhead (*Sebastolobus alascanus*) and the longspine thornyhead (*S. altivelis*). Only the shortspine thornyhead is of commercial importance. It is a demersal species found in deep water, from 93 m to 1,460 m, from the Bering Sea to Baja California (Ianelli and Gaichas 1999). Little is known about thornyhead life history. Like other rockfish, they are long-lived and slow growing. The maximum recorded age is probably in excess of 50 years, and females do not become sexually mature until an average age of 12 to 13 and a length of about 21 cm. Thornyheads spawn large masses of buoyant eggs during the late winter and early spring (Pearcy 1962). Juveniles are pelagic for the first year. Yang (1993, 1996) showed that shrimp were the top prey item for shortspine thornyheads in the GOA, while cottids were the most important prey item in the Aleutian Islands. Until recently, thornyheads were not targeted by the commercial fishery. However, they are now among the most valuable rockfish species and are harvested by trawl and longline gear. Most of the domestic harvest is exported to Japan. Thornyheads are taken with some frequency in the longline fishery for sablefish and cod, and are often part of the bycatch of trawlers concentrating on pollock and other rockfish species.

In the GOA, shortspine thornyheads are assessed with an age-structured model incorporating data from two fisheries (longline and trawl) and two types of survey data. Bottom trawl surveys have been conducted every three years in the GOA during June through August and provide a limited time-series of abundance since 1977. Longline surveys occur annually and extend into the deeper waters (300 to 800 m) of shortspine thornyhead habitat. Both surveys provide estimates of the size distributions of their respective catches. These are used in the stock assessment model in place of age compositions, because extensive age determinations on this species are currently impractical, given the difficulties in interpretation of their otoliths. Biologically, the greatest area of uncertainty for this species is in their longevity and natural mortality rate. Currently, NMFS scientists believe they are slow-growing and long-lived fish that are relatively sedentary on the ocean floor. Survey and fishery catch rates indicate that they are relatively evenly distributed within their habitat and, like many other groundfish species, do not tend to form dense aggregations. This distribution pattern is important in interpreting the survey results because the assumptions implied in area-swept methods for the bottom trawl gear are likely to be satisfied (for further information on surveys see Section 2.7.3). Fishery data include estimates of the total catch and size distribution information by gear type. The estimated biomass for 2000 is 23,084 mt, and the recommended ABC is 2,360 mt. The Council has adopted this value for both the 2000 TAC and OFL harvest levels.

In the eastern Bering Sea and Aleutian Islands, thornyheads are managed as part of, and are the primary species in, the other rockfish management assemblage. The assessment is based on the most recent catch and survey data. Traditionally, the biomass estimates (split according to management area) from all bottom trawl surveys (eastern Bering Sea shelf/slope and Aleutian Islands) are averaged over all years to obtain the best estimates of biomass for the species in this complex. In 1999, this procedure produced a biomass estimate of 7,030 mt in the eastern Bering Sea, and a biomass estimate of 13,000 mt in the Aleutian Islands. The great majority of this biomass is composed of thornyhead rockfish. In 1996, the SSC determined that a reliable estimate of the natural mortality rate (M) existed for the species in this subcomplex, and that other rockfish in the eastern Bering Sea and Aleutian Islands therefore qualified for management under Tier 5 (Appendix 1, Amendment 44). The accepted estimate of M for these species in both areas is 0.07. F_{ABC} was set at the maximum value allowable under Tier 5, which is 75 percent of M , or 0.053. Multiplying this rate by the best estimate of

complex-wide biomass gives an ABC of 369 mt in the eastern Bering Sea and 685 mt in the Aleutian Islands. The plan team's OFLs were determined from the Tier 5 formula, where setting $F_{OFL} = M$ gives an OFL of 492 mt in the eastern Bering Sea and 913 mt in the Aleutian Islands.

Other Rockfish Species

Numerous other rockfish species of the genus *Sebastes* have been reported in the GOA and BSAI (Eschmeyer et al. 1984), and several are of commercial importance. Most are demersal or semidemersal, with different species occupying different depth strata (Kramer and O'Connell 1988). All are viviparous (Hart 1973). Life history attributes of most of these rockfish are poorly or virtually unknown. Because they are long-lived and slow growing, natural mortality rates are probably low (less than 0.10). The diet of species for which dietary information exists seems to consist primarily of planktonic invertebrates (Yang 1993 and 1996). Other rockfish species are taken both in directed fisheries and as bycatch in trawl and longline fisheries.

In the GOA, although the other slope rockfish management group comprises 17 species, 6 species alone make up 95 percent of the catch and estimated abundance: sharpchin (*Sebastes zacentrus*), redstripe (*S. Proriger*), harlequin (*S. Variiegatus*), yellowstripe (*S. Reedi*), silvergrey (*S. Brevispinas*), and redbanded rockfish (*S. Babcocki*). Sharpchin rockfish fall into Tier 4, and the remaining species fall into Tier 5 of the ABC and OFL definitions. The OFL fishing mortality rate for the other species is the $F = M$ rate of 0.10 for redstripe rockfish, 0.04 for silvergrey rockfish, and 0.06 for all the other species (except sharpchin rockfish). The F_{ABC} for sharpchin rockfish is $F = M = 0.05$, which is less than the maximum allowable rate of $F_{40\%} = 0.055$. For the other species, the maximum allowable fishing mortality rate for ABC is the $F = 0.75M$ rate, which is 0.075 for redstripe rockfish, 0.030 for silvergrey rockfish, and 0.045 for the remaining species. These rates result in the recommended stock assessment ABC of 4,900 mt for other slope rockfish. The current Council ABC and TAC levels are equivalent to this value. The ABC and TAC for the sharpchin rockfish component of the other slope rockfish being set more conservatively than the maximum prescribed under the definitions results in less risk of the F_{ABC} and TAC being an overly aggressive harvest rate for other slope rockfish. This affords more protection to the stocks, given the variability and uncertainty associated with the abundance.

Heifetz and Ackley (1997) analyzed bycatch (not necessarily discarded) in GOA rockfish fisheries. Bycatch rates of other slope rockfish are highest in the pelagic shelf rockfish and Pacific ocean perch fisheries. Information on bycatch of other slope rockfish in non-rockfish fisheries has not been analyzed. Discard rates (discards divided by total catch) of other slope rockfish from 1995 to 1999 ranged from 52 to 76 percent (Heifetz et al. 1999). In 1999, about 544 mt of other slope rockfish were discarded, compared to a total catch of 789 mt. High discard rates are seen because many other slope rockfish species are small in size and have a low economic value; therefore, fishermen have little incentive to retain these fish.

Prey of other slope rockfish is not documented for the GOA. Predators of other slope rockfish are also not well documented, but likely include larger fish, such as Pacific halibut, which are known to prey on other rockfish species.

3.3.1.11 Atka Mackerel

Bering Sea/Aleutian Islands

Atka mackerel are distributed from the east coast of the Kamchatka Peninsula, throughout the Aleutian Islands and the eastern Bering Sea, and eastward through the GOA to southeast Alaska (Wolotira et al. 1993). Their current center of abundance is in the Aleutian Islands, with marginal distributions extending into the southern Bering Sea and into the western GOA (Lowe and Fritz 1999a). Atka mackerel are one of the most abundant

groundfish species in the Aleutian Islands, where they are the target of a directed trawl fishery (Lowe and Fritz 1999a). Adults are semipelagic and spend most of the year over the continental shelf in depths generally less than 200 m. Adults migrate annually to shallow coastal waters during spawning, forming dense aggregations near the bottom (Morris 1981, Musienko 1970). In Russian waters, spawning peaks in mid-June (Zolotov 1993) and in Alaskan waters in July through October (McDermott and Lowe 1997). Females deposit adhesive eggs in nests or rocky crevices. The nests are guarded by males until hatching occurs (Zolotov 1993). The first in situ observations of spawning habitat in Segum Pass were documented in August, 1999 (Robert Lauth, NMFS Alaska Fisheries Science Center – personal communication). Genetic studies indicate that Atka mackerel form a single stock in Alaskan waters (Lowe et al. 1998). However, growth rates can vary extensively among different areas (Kimura and Ronholt 1988, Lowe et al. 1998, Lowe and Fritz 1999a). Age and size at 50 percent maturity has been estimated at 3.6 years and 33–38 cm, respectively (McDermott and Lowe 1997). Atka mackerel are a relatively short-lived groundfish species. A maximum age of 15 years has been noted, however most of the population is probably less than 10 years old. Natural mortality estimates vary extensively, and estimates have ranged from 0.12 to 0.74 as determined by various methods (Lowe and Fritz 1999a). For stock assessment purposes, a value of 0.3 is used (Lowe and Fritz 1999a).

Atka mackerel are an important component in the diet of other commercial groundfish, mainly arrowtooth flounder, Pacific halibut, and Pacific cod; seabirds, mainly tufted puffins; and marine mammals, mainly northern fur seals and Steller sea lions (Byrd et al. 1992, Livingston et al. 1993, Fritz et al. 1995, Yang 1996). Atka mackerel are also components in the diets of the following marine mammals and seabirds: harbor seals, Dall's porpoise, thick-billed murre, and horned puffins (Yang 1996). The diets of commercially important groundfish species in the Aleutian Islands during the summer of 1991 were analyzed by Yang (1996). More than 90 percent of the total stomach content (by weight) of Atka mackerel in the study was made up of invertebrates, with less than 10 percent made up of fish. Euphausiids (mainly *Thysanoessa inermis* and *T. rachii*) were the most important prey items, followed by calanoid copepods. The two species of euphausiids comprised 55 percent of the total stomach contents, and copepods comprised 17 percent. Larvaceans and hyperiid amphipods had high frequencies of occurrence (81 percent and 68 percent, respectively), but comprised less than 8 percent of the total stomach content weight. Squid was another item in the diet of Atka mackerel; it had a frequency of occurrence of 31 percent, but comprised only 8 percent of total stomach content. Atka mackerel are known to eat their own eggs. Yang (1996) found that Atka mackerel eggs comprised 3 percent of the total stomach content and occurred in 9 percent of the analyzed Atka mackerel stomachs. Walleye pollock were the second most important prey fish of Atka mackerel, comprising about 2 percent of the total stomach content. Myctophids, bathylagids, zoarcids, cottids, stichaeids, and pleuronectids were minor components of the Atka mackerel diet; each category comprised less than 1 percent of the total stomach content.

Atka mackerel are a difficult species to survey because they do not have a swim bladder and are therefore poor targets for hydroacoustic surveys. They prefer rough and rocky bottoms that are difficult to sample with the current survey gear, and their schooling behavior and patchy distribution result in survey estimates with large variances. Complicating the difficulty in surveying Atka mackerel is the low probability of encountering schools in the GOA, where the abundance is lower and their distribution is patchier relative to the BSAI. Because of this, it has not been possible to estimate population trends for the species in the GOA. The stock assessment in the Aleutian Islands is based on NMFS triennial trawl surveys, as well as total catch and catch at age data from the commercial fishery.

BSAI Atka mackerel are assessed with an age-structured model incorporating fishery and survey catch data and age compositions. Fishery catch statistics (including discards) are estimated by the NMFS Regional Office. These estimates are based on the best blend of observer reported catch and weekly production reports. Stock assessments include catch history, characterizations of the fishery, key life history parameters, survey

and model-estimated abundance trends, historical exploitation rates, reference fishing mortality rates, projected catch and abundance trends for a range of fishing mortalities and recruitment assumptions, and a recommended harvest rate and catch for the upcoming year. The results of the analyses, which are updated annually, are presented in the BSAI Atka mackerel stock assessment, which is incorporated into the BSAI SAFE report.

In 1999, Atka mackerel fell into Tier 3a of the ABC and OFL definitions, which requires reliable estimates of biomass, $B_{40\%}$, $F_{35\%}$, and $F_{40\%}$. Under the definitions and current stock conditions, the OFL fishing mortality rate is $F_{35\%}$ estimated to be 0.42 for Atka mackerel, which equated to a yield of 119,300 mt (Lowe and Fritz 1999a). The maximum allowable fishing mortality rate for ABC (F_{ABC}) is $F_{40\%}$, estimated to be 0.35 for Atka mackerel in 1999, which translated to a yield of 102,700 mt (Lowe and Fritz 1999). In 1999, the stock assessment ABC recommendation for the 2000 Atka mackerel fishery was below the maximum rate prescribed under Tier 3a, to provide a more risk averse harvest rate and to accommodate uncertainty. The stock assessment F_{ABC} is 0.23, which translated to a yield of 70,800 mt. A recommendation lower than $F_{40\%}$ was recommended in the 1999 stock assessment because: (1) stock size as estimated by the age-structured analysis has declined by approximately 60 percent since 1991; and (2) the 1997 Aleutian trawl survey biomass estimate was about 50 percent lower than the 1991 and 1994 survey estimates.

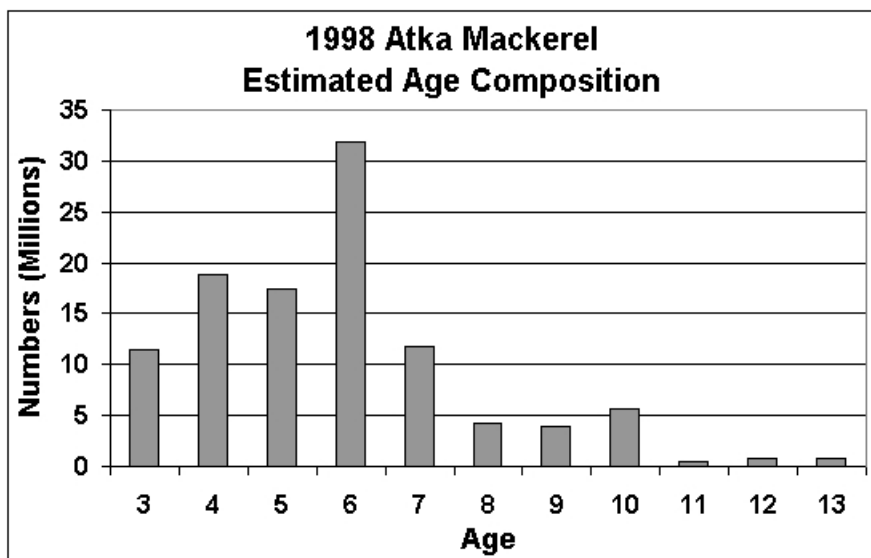


Figure 3.3-6 Estimated age composition of Bering Sea and Aleutian Islands Atka mackerel, 1998. Source: Lowe and Fritz (1999a)

The 1998 age and size distributions of BSAI Atka mackerel are discussed in Lowe and Fritz (1999a). The 1998 age composition of Atka mackerel from the fishery is shown in Figure 3.3-6. The age composition is dominated by a recent strong 1992 year class (6-year-olds), and there is still evidence of the strong 1988 year class (10-year-olds) in the population. The estimated mean age of the 1998 fishery age composition is 6 years. The current fishery tends to select fish aged 3 to 12 years old (Lowe and Fritz 1999a). It is not known how the age composition of the population would look in an unfished population.

The directed fishery for Atka mackerel is prosecuted by catcher/processor bottom trawlers. The fishery patterns generally reflect species behavior in that the fishery is highly localized, occurring in the same few locations each year, generally at depths between 100 and 200 m (Lowe and Fritz 1999a). Observed Atka

mackerel fishery trawl locations during 1998 and 1999 in the Aleutian Islands are shown in Figures 3.3-7 and 3.3-8. Important Atka mackerel fishery locations include Seguam Bank, Tanaga Pass, north of the Delarof Islands, Petrel Bank, south of Amchitka Island, east and west of Kiska Island, and on the seamounts and reefs near Buldir Island.

Since 1979, the Atka mackerel fishery has occurred largely within areas designated as Steller sea lion critical habitat. While total removals from critical habitat may be small in relation to total biomass estimates in the Aleutian Islands, fishery harvest rates in localized areas may have been high enough to affect the availability of prey to Steller sea lions (Lowe and Fritz 1997a). The localized pattern of fishing for Atka mackerel apparently does not affect fishing success from one year to the next, since local Aleutian Islands populations appear to be replenished by immigration and recruitment. However, this pattern could create temporary reductions in the size and density of localized Atka mackerel populations, which could affect Steller sea lion foraging success during the time the fishery is operating and for a period of unknown duration after the fishery is closed.

To address the possibility that the fishery creates localized depletions of Atka mackerel and adversely modifies Steller sea lion critical habitat by disproportionately removing prey in June 1998, the Council passed a fishery management regulatory amendment that proposed a four-year timetable to temporally and spatially disperse and reduce the level of Atka mackerel fishing within Steller sea lion critical habitat in the BSAI. The temporal dispersion is accomplished by dividing the BSAI Atka mackerel TAC into two equal seasonal allowances. The first allowance is made available for directed fishing from January 1 to April 15 (A season), and the second seasonal allowance is made available from September 1 to November 1 (B season). The spatial dispersion is accomplished through maximum catch percentages of each seasonal allowance that can be caught within Steller sea lion critical habitat as specified for the central and western Aleutian Islands. No critical habitat closures are established for the eastern subarea, but the 20-nm trawl exclusion zones around the Seguam and Agligadak rookeries that have been in place only for the pollock A-season, are in effect year-round. The regulations implementing these management changes became effective January 22, 1999. The four-year timetable for spatial dispersion of the Atka mackerel fishery outside of critical habitat is as follows:

Aleutian Islands

<u>Year(s)</u>	<u>Area 542</u>		<u>Area 543</u>	
	<u>Inside CH</u>	<u>Outside CH</u>	<u>Inside CH</u>	<u>Outside CH</u>
1999	80%	20%	65%	35%
2000	67%	33%	57%	43%
2001	54%	46%	49%	51%
2002	40%	60%	40%	60%

CH = Critical Habitat

Relative to 1998, the biggest shift in the distribution of fishing effort was observed in Area 542, where effort shifted to Petrel Bank in 1999 (Figure 3.3-8).

Atka mackerel are not commonly caught as bycatch in other directed fisheries. The largest amounts of discards, which are likely undersized fish, occur in the directed Atka mackerel trawl fisheries. Recent discard rates (discards/retained catch) of Atka mackerel in the directed fishery have been below 10 percent (Lowe and

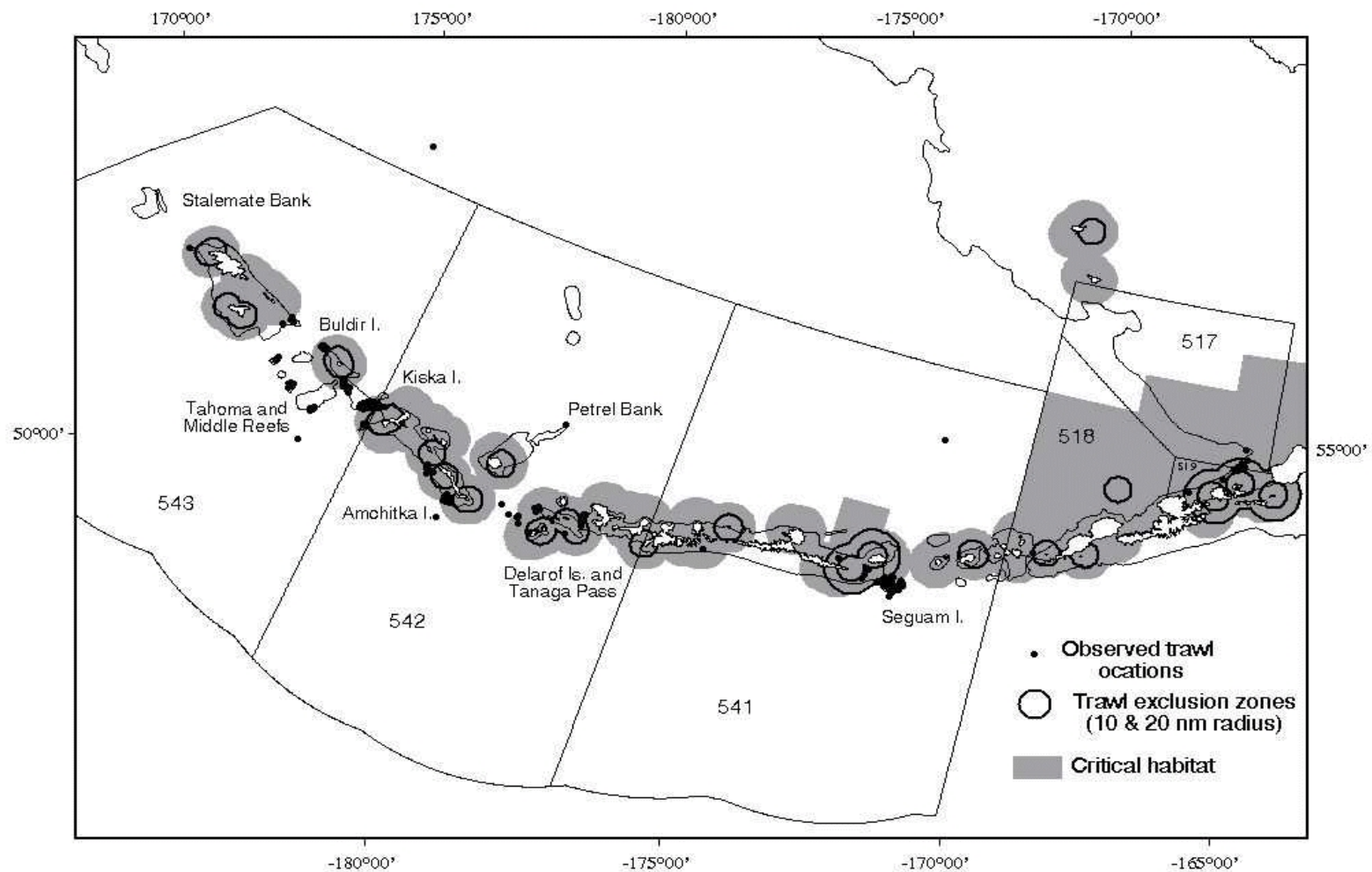


Figure 3.3-7 Observed Atka mackerel fishery locations in the Aleutian Islands region in 1998. Trawl exclusion zones, Steller sea lion critical habitat zones around rookeries and haulouts, the 200-m isobath, management Areas 541–543, and names of locations fished are shown. Source: NMFS

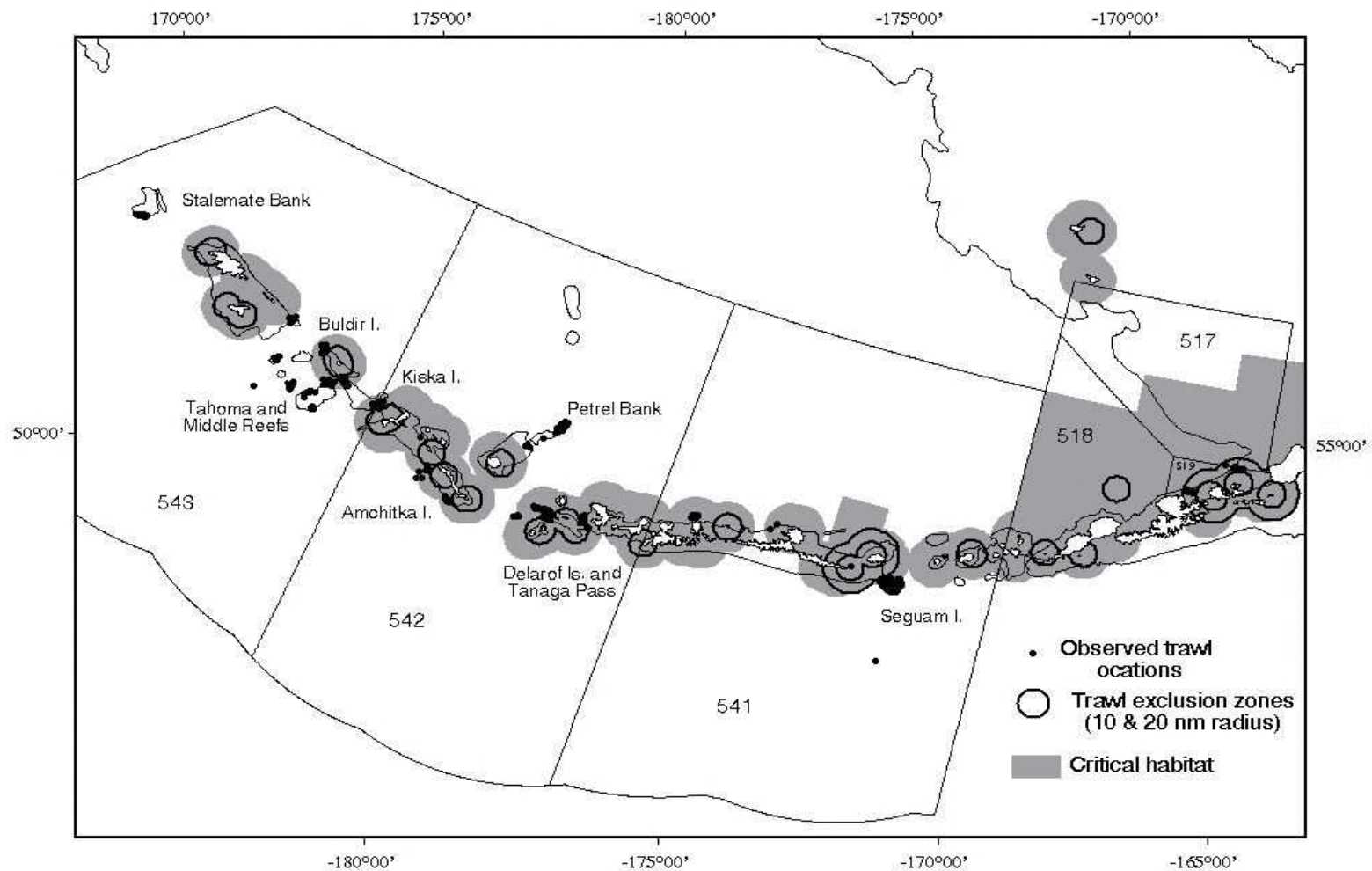


Figure 3.3-8 Observed Atka mackerel fishery locations in the Aleutian Islands region in 1999. Trawl exclusion zones, Steller sea lion critical habitat zones around rookeries and haulouts, the 200-m isobath, management Areas 541–543, and names of locations fished are shown. Source: NMFS

Fritz 1999a). Atka mackerel are also caught as bycatch in the trawl Pacific cod and rockfish (primarily Pacific ocean perch, sharpchin, and northern rockfish) fisheries. It is difficult to discern the level of natural bycatch of Atka mackerel in the rockfish fisheries, as vessels may actually be targeting Atka mackerel in particular hauls, but overall they are designated as targeting rockfish on a particular trip. In 1998, 4,597 mt of Atka mackerel were discarded in the directed rockfish fishery as compared to 1,072 mt discarded in all other fisheries.

Gulf of Alaska

No reliable estimate exists of current Atka mackerel biomass in the GOA. Atka mackerel have not been commonly caught in the GOA triennial trawl surveys. It has been determined that the general GOA groundfish bottom trawl survey does not assess the GOA portion of the Atka mackerel stock well, and resulting biomass estimates have little value as absolute estimates of abundance or as indices of trend (Lowe and Fritz 1999a). Because of this lack of fundamental abundance information, GOA Atka mackerel are not assessed with a model. The stock assessment that is done does not utilize abundance estimates from the trawl survey; consists of descriptions of catch history, length and age distributions from the fishery (1990–1994) and length and age distributions from the trawl surveys (1990, 1993, and 1996). This information is presented in the GOA Atka mackerel stock assessment, which is incorporated into the GOA SAFE report.

GOA Atka mackerel fall into Tier 6 of the ABC and OFL definitions, which define the OFL level as average catch from 1978 to 1995 and ABC as not exceeding 75 percent of OFL. The average annual catch from 1978 to 1995 is 6,200 mt; thus ABC cannot exceed 4,700 mt. The current ABC recommendation from the stock assessment is below the maximum prescribed under Tier 6, to provide a very conservative harvest strategy given the uncertainty about GOA Atka mackerel abundance. The 1999 stock assessment for the 2000 fishery recommended an ABC of 600 mt, with the intention of precluding a directed fishery, but providing for bycatch needs in other trawl fisheries. An ABC lower than the maximum prescribed under Tier 6 was recommended for the following reasons.

1. When past ABCs were lower than 4,700 mt (approximately 3,000 mt in 1994), it was shown that the fishery might have created localized depletions of Atka mackerel even at those catch levels (appendix in Lowe and Fritz 1996). This analysis indicated that the fishery was very efficient in removing fish from local areas and at rates that far surpassed the target harvest rate.
2. Analyses of local fishery catch per unit of effort (CPUE) indicated that Atka mackerel populations may have declined significantly between 1992 and 1994 (appendix in Lowe and Fritz 1996), reflecting the trend of the Aleutian Islands Atka mackerel population during that period, which has continued to decline since 1994 (Lowe and Fritz 1999b).
3. The GOA Atka mackerel population appears to be particularly vulnerable to fishing pressure because of sporadic movement of fish eastward from the Aleutian Islands.

Age and size distributions of GOA Atka mackerel are discussed in Lowe and Fritz (1999b). The most recent size and age distributions are from the 1996 and 1993 trawl surveys, respectively. Male and female size distributions had mean lengths of 45 and 47 cm, respectively. A mode of fish from 45 to 47 cm represented the 1988 year class. It appears as though little recent recruitment has occurred in the GOA population. Currently, no directed fishery for GOA Atka mackerel occurs. Atka mackerel are caught as bycatch and the selectivity of Atka mackerel by the other fisheries is unknown. As such, Atka mackerel in the GOA are currently managed as bycatch in the pollock, Pacific cod, Pacific ocean perch, and northern rockfish fisheries.

The low level of TAC likely precludes directed targeting of Atka mackerel on a haul-by-haul basis, and the catches of Atka mackerel in other directed fisheries may represent true bycatch.

The diets of commercially important groundfish species in the GOA during the summer of 1990 were analyzed by Yang (1993). Atka mackerel were not sampled as a predator species. However, it is probably a reasonable assumption that the major prey items of GOA Atka mackerel would likely be euphausiids and copepods as was found in Aleutian Islands Atka mackerel (Yang 1996). The abundance of Atka mackerel in the GOA is much lower compared to the Aleutian Islands. Atka mackerel appeared only as a minor component in the diet of arrowtooth flounder in the GOA (Yang 1993).

3.3.1.12 Squid and Other Species

Squid are found throughout the Pacific Ocean. They are not currently the target of groundfish fisheries in the GOA or BSAI, although they are taken as bycatch in pollock and rockfish trawl fisheries. The red (magistrate) armhook squid is probably the best known species found in Alaskan waters. It is abundant over continental slopes throughout the North Pacific Ocean from Oregon to southern Japan (Nesis 1987). It is the basis of fisheries in both Russian and Japanese waters. Little is known about the reproductive biology of squid. Fertilization is internal and juveniles have no larval stage. Eggs of inshore species are often enveloped in a gelatinous matrix attached to substrate, while the eggs of offshore species are extruded as drifting masses. The red armhook squid appears to spawn in the spring and to live as long as 4 years, though most die after spawning at one year to 16 months (Arkhipkin et al. 1996). Perez (1990) estimated that squid comprise over 80 percent of the diet of some whales. Seabirds and some salmon species are also known to feed heavily on squid at certain times of the year.

In the BSAI FMP, squid are grouped in a *squid and other species* group, which is made up of squid (considered separately) and sculpin, skate, shark, and octopi (which comprise the true other species category). Because data are insufficient to manage each of the other species groups separately, they are considered collectively. Neither squid nor any of the species in the other species category are currently targeted by the BSAI and GOA groundfish fisheries. As such, they are only caught as bycatch by fisheries targeting groundfish. Table 3.3-1 presents bycatch data for other species and squid (as well as forage and miscellaneous fish) for 1999 BSAI and GOA groundfish fisheries by fishery and gear. Beginning in 1999, smelt was removed from the other species category and placed—along with a wide variety of other fish and crustaceans including krill, deep-sea smelts, and lantern fishes—in the forage fish category. This action was accomplished through Amendments 36 and 39 (Appendix 1) to the BSAI and GOA groundfish FMPs. These amendments place specific catch percentage limits for forage fish on all groundfish fishery participants in order to prevent the development of directed forage fish fisheries.

Assessment data are not available for squid from NMFS surveys because of their mainly pelagic distribution over deep water. Information on the distribution, abundance, and biology of squid stocks in the eastern Bering Sea and Aleutian Islands is generally lacking. Red armhook squid (*Berryteuthis magister*) predominates in commercial catches in the eastern Bering Sea and GOA, and *Onychoteuthis borealijaponicus* is the principal species encountered in the Aleutian Islands.

Forty-one sculpin species were identified in the eastern Bering Sea, 22 species in the Aleutian Islands (Bakkala 1993, Bakkala et al. 1985, Ronholt et al. 1985). During these same surveys, 15 skate species were identified, but inadequate taxonomic keys for this family may have resulted in more species being identified than actually exist. Species that have been consistently identified during surveys are the Alaska skate (*Bathyraja parmifera*), big skate (*Raja binoculata*), longnose skate (*R. rhina*), starry skate (*R. stellulata*), and Aleutian skate (*B.*

Table 3.3-1

Estimated Catches of Other Species^a, Squid, Forage Fish, and Miscellaneous Fish by Groundfish Fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska by Target Species Fishery and Gear, 1999, in Metric Tons

Target Groundfish Species	Gear	Other Species						Forage Fish	Miscellaneous Fish
		Skate	Shar k	Sculpin	Octopus	Total	Squid		
I. BERING SEA AND ALEUTIAN ISLANDS									
Atka mackerel	Trawl	96	0 ^c	285	0 ^c	382	5	- ^b	75
Pacific cod	Trawl	831	8	954	23	1,817	2	2	132
Pacific cod	Pot	0 ^c	- ^b	649	260	909	0 ^c	- ^b	10
Pacific cod	Longline	9,625	105	1,139	21	10,890	0	0	113
Pacific cod	All	10,455	113	2,742	304	13,615	2	2	255
Flatfish	Trawl	11,750	179	9,101	11	21,041	60	20	2,589
Flatfish	Longline	5	NA	0 ^c	NA	5	NA	- ^b	42
Flatfish	All	11,755	179	9,101	11	21,045	60	20	2,630
Rockfish	Trawl	53	3	21	0 ^c	77	5	0 ^c	55
Rockfish	Longline	9	1	0 ^c	0 ^c	11	- ^b	- ^b	223
Rockfish	All	62	4	21	0 ^c	88	5	0 ^c	278
Pollock	Pelagic trawl	314	104	40	0 ^c	458	403	38	209
Pollock	Bottom trawl	42	2	18	1	62	4	1	10
Pollock	All	355	105	58	1	520	406	39	219
Rock sole	Trawl	207	0 ^c	152	12	371	NA	0 ^c	69
Sablefish	Pot	0 ^c	NA	NA	0 ^c	0 ^c	NA	- ^b	0
Sablefish	Longline	105	21	0 ^c	0 ^c	126	- ^b	- ^b	4,730
Sablefish	All	105	21	0 ^c	0 ^c	126	- ^b	- ^b	4,730
Turbot	Trawl	11	NA	3	0 ^c	15	4	0 ^c	12
Turbot	Pot	1	- ^b	- ^b	0 ^c	1	0 ^c	- ^b	0
Turbot	Longline	273	203	2	0 ^c	479	- ^b	- ^b	3,840
Turbot	All	285	203	6	0 ^c	494	4	0 ^c	3,852
Yellowfin sole	Trawl	566	1	935	2	1,503	NA	2	328
All	Trawl	13,827	295	11,492	48	25,662	478	63	3,469
	Pot	1	- ^b	649	260	909	0 ^c	- ^b	10
	Longline	10,017	330	1,141	22	11,509	0 ^c	0 ^c	8,947
All	All	23,844	625	13,282	329	38,080	478	63	12,426

Table 3.3-1 (Cont.) Estimated Catches of Other Species^a, Squid, Forage Fish, and Miscellaneous Fish by Groundfish Fisheries in the Bering Sea, Aleutian Islands, and Gulf of Alaska by Target Species Fishery and Gear, 1999, in Metric Tons

Target Groundfish Species	Gear	Other Species						Forage Fish	Miscellaneous Fish
		Skate	Shark	Sculpin	Octopus	Total	Squid		
II. GULF OF ALASKA									
Pacific cod	Trawl	216	10	98	3	238	0 ^c	15	24
Pacific cod	Pot	0 ^c	1	111	115	118	- ^b	45	13
Pacific cod	Longline	333	230	129	5	675	- ^b	1	5
Pacific cod	All	549	241	338	123	1,032	0	61	42
Flatfish	Trawl	470	46	58	9	490	7	9	350
Flatfish	Longline	0 ^c	- ^b	- ^b	- ^b	- ^b	- ^b	- ^b	4
Flatfish	All	470	46	58	9	490	7	9	353
Rockfish	Trawl	46	5	26	0 ^c	17	6	101	123
Rockfish	Longline	27	58	0 ^c	- ^b	- ^b	- ^b	10	6
Rockfish	All	73	63	26	0 ^c	17	6	111	129
Pollock	Bottom trawl	20	63	0 ^c	0 ^c	83	2	2	107
Pollock	Pelagic trawl	2	131	3	0 ^c	118	18	23	120
Pollock	All	22	194	4	0 ^c	201	20	25	227
Sablefish	Trawl	0 ^c	- ^b	0 ^c	0 ^c	- ^b	0 ^c	0 ^c	1
Sablefish	Longline	200	126	0 ^c	0 ^c	19	1	2	9,338
Sablefish	All	201	126	0 ^c	0 ^c	19	1	2	9,339
All	Trawl	754	255	185	13	946	33	151	724
All	Pot	0 ^c	1	111	115	118	- ^b	45	13
All	Longline	1,030	460	187	15	1,184	8	22	9,703
All	All	1,784	716	484	143	2,248	41	218	10,440

Notes: ^aForage fish are myctophids, osmerids, bathylagids, sandfish, sand lance, gunnells, and pricklebacks. Miscellaneous fish are mostly grenadiers, but also include greenlings, poachers, lumpsuckers, ronquils, gastropods, fish waste, snipe eels, eelpouts, hagfish, pomfrets, and snailfish.

^bless than 0.01 mt

^c0 less than 0.01 and less than 0.5 mt of estimated catch.

NA – data not available

Source: Observer and NMFS blend data

aleutica). Biomass estimates of sculpin and skate from demersal trawl surveys serve as valuable indices of their relative abundance.

While biomass estimates have been made for sharks and octopuses, the NMFS bottom trawl surveys are not designed to adequately sample the realms they inhabit. Sharks are rarely taken during demersal trawl surveys in the Bering Sea; however, spiny dogfish (*Squalus acanthias*) is a species usually caught, and the Pacific sleeper shark (*Somniosus pacificus*) has been taken on occasion. Two octopus species have been recorded: *Octopus dofleini* is the principal species, *Opisthoteuthis californica* appears only intermittently.

Many species in the squid and other species assemblage are important prey for marine mammals and birds, as well as commercial groundfish species. Squid and octopus are consumed primarily by marine mammals such as Steller sea lions (Lowry et al. 1982), northern fur seals (Perez and Bigg 1986), harbor seals (Lowry et al. 1982, Pitcher 1980b), sperm whales (Kawakami 1980), Dall's porpoise (Crawford 1981), Pacific white-sided dolphins (Morris et al. 1983), and beaked whales (Loughlin and Perez 1985). Sculpins have also been found in the diet of harbor seals (Lowry et al. 1982).

Examination of eastern Bering Sea and Gulf of Alaska Biomass Estimates for Squid and Other Species

Data from NMFS surveys provide the only abundance estimates for the various groups and species comprising the other species category. Biomass estimates for the eastern Bering Sea are from a standard survey area of the continental shelf. The 1979, 1981, 1982, 1985, 1988, and 1991 data include estimates from continental slope waters (200–1,000 m in 1979, 1981, 1982, and 1985; 200–800 m in 1988 and 1991), but data from other years do not. Slope estimates were usually 5 percent or less of the shelf estimates, except for grenadiers. Stations as deep as 900 m were sampled in the 1980, 1983, and 1986 Aleutian Islands bottom trawl surveys, while surveys in 1991 and 1994 obtained samples to a depth of only 500 m.

Since the survey biomass estimates for species other than squid vary substantially from year to year due to different distributions of the component species, it is probably more reliable to estimate current biomass by averaging estimates of recent surveys. The average biomass of other species from the last three eastern Bering Sea surveys (1997, 1998, and 1999) is 561,600 mt; adding the estimate from the 1997 Aleutian Islands survey (48,800 mt) yields a total BSAI other species biomass estimate of 610,400 mt.

Biomass estimates from NMFS surveys illustrate that sculpins were the major component of this group until 1986, after which skate biomass exceeded that of sculpins. The abundance of skate increased between 1985 and 1990 (when a high of 583,800 mt survey biomass was observed), but had declined to about 370,000 mt in 1999. The abundance of sculpin remained relatively stable through 1998, but declined in 1999 to the lowest biomass estimate since 1975.

Trends in the biomass of GOA other species (shark, skate, sculpin, smelt, octopus, and squid) were investigated using the NMFS triennial trawl survey data from 1984 through 1999. Any discussion of biomass trends should be viewed with the following caveats in mind:

1. Survey efficiency may have increased for a variety of reasons between 1984 and 1990, but should be stable after 1990 (Robin Harrison, NMFS Alaska Fisheries Science Center - personal communication).
2. Surveys in 1984, 1987, and 1999 included deeper strata than the 1990–1996 surveys. Therefore, the biomass estimates for deeper-dwelling components of the other species category are not comparable across all years.

The average biomass within the other species category, using all six survey biomass estimates, is 160,000 mt. The most recent estimate of other species biomass (1999) is 213,000 mt. Skates represent 30 to 40 percent of the other species biomass from all surveys and are the most common species in each year except 1984 when sculpin biomass was highest within the category. Total biomass for the other species category increased between 1984 and 1999. This is the result of apparent increases in skate, shark, and smelt biomass, some of which may be difficult to resolve from changes in survey efficiency. Sculpin biomass appears relatively stable over this period.

Individual species biomass trends were evaluated for the more common and easily identified shark and sculpin species encountered by the triennial trawl surveys. In general, the increasing biomass trend for the shark species is a result of increases in spiny dogfish and sleeper shark biomass between 1990 and 1999. Salmon shark biomass has been stable to decreasing, according to this survey, but salmon shark is unlikely to be well sampled by a bottom trawl (as evidenced by the high uncertainty in the biomass estimates). It should be noted that both salmon shark and Pacific sleeper shark biomass estimates may be based on a very small number of individual tows in a given survey. No salmon sharks were encountered in the 1999 survey, despite reports of their increased abundance in other areas of the GOA.

Individual sculpin species display divergent biomass trends between 1984 and 1999. While the biomass of bigmouth sculpins (*Hemitripterus bolini*) decreased over the survey period, great sculpin (*Myoxocephalus polyacanthocephalus*) biomass remained relatively stable, and yellow Irish lord (*Hemiliepidotus jordani*) biomass increased. Yellow Irish lord biomass appears to have increased over time despite general stability in the number of hauls where the species occurred, whereas bigmouth sculpins were encountered in fewer hauls each year. Uncertainty in these estimates varies between years.

In addition to sharks and sculpins, available biomass estimates for grenadiers (Macrouridae), which are not included in the other species category, were examined. The species most commonly encountered in the triennial trawl surveys was the giant grenadier (*Albatrossia pectoralis*). The Pacific grenadier (*Coryphaenoides acrolepis*) was present, but with much lower estimated biomass in all years. Survey coverage of deeper strata is particularly important to grenadier biomass estimates; therefore, the 1990–1996 survey estimates are considered to be of little use for detecting trends in grenadier abundance.

Current Stock Assessment and OFL/ABC and TAC Determinations

No reliable biomass estimates for squid exist, and no stock assessment per se. Sobolevsky (1996) cites an estimate of 4 million tons for the entire Bering Sea made by squid biologists at the Pacific Research Institute of Fisheries and Oceanography (Shuntov 1993), and an estimated 2.3 million tons for the western and central Bering Sea (Radchenko 1992), but admits that squid stock abundance estimates have received little attention. NMFS bottom trawl surveys almost certainly underestimate squid abundance. Squid catches and ABCs are almost certainly a very small percentage of the total squid biomass in the eastern Bering Sea and GOA. BSAI squid ABC and OFL are set using criteria in Tier 6, as described in Amendment 44 to the BSAI FMP, given the lack of data on squid population dynamics and biomass. OFL is set equal to the average annual catch from 1978 to 1995 (2,624 mt), while ABC is capped at no greater than 75 percent of OFL (1,970 mt). As currently defined, BSAI squid ABC and OFL values would remain constant in the future, unless different methodologies were employed to assess squid abundance (e.g., analysis of fishery CPUE data). This methodology change could occur under any of the alternatives considered. The BSAI squid TAC has been set equal to the stock-assessment-recommended ABC by the Council.

Reliable biomass estimates exist for two groups (skates and sculpins) that comprise the bulk of the biomass and fishery catches in the other species category. Survey biomass estimates for shark, smelt, and octopus, while not reliable, represent the best data available on the abundance of these species. A single estimate of M for this diverse assemblage, while not known, is conservatively estimated at 0.2. OFL for the other species assemblage is set using the criteria in Tier 5 (as described in Amendment 44), where $F_{OFL} = M$, and $OFL = M \times (\text{total other species survey biomass})$. Using Tier 5 criteria, ABC is capped at 75 percent of OFL. However, rather than use this method, since 1978, the other species ABC has been calculated as the average annual catch in order to avoid potential five-fold increases in other species catches that could occur if ABC were set at 75 percent of OFL. In 1998 (for the 1999 fishery), the Council began a 10-step increase toward full $F = M$ exploitation strategy for the other species complex by implementing the first 10 percent of the difference

between that strategy and average catch since 1978. For the 2000 fishery, the Council stopped the stepwise increase and kept the ABC at a level approximately 10 percent higher than the stock assessment author's recommendation. BSAI other species TAC has been set equal to the other species ABC by the Council. A 2000 ABC for the BSAI other species category set using this process (31,360 mt) represents an exploitation rate of about 5 percent of the best estimate of current biomass (610,400 mt). This estimate was obtained by averaging the three most recent eastern Bering Sea bottom trawl survey estimates of other species biomass (561,600 mt from 1997 to 1999), and adding the most recent Aleutian Islands bottom trawl estimate (48,800 mt from 1997).

The annual TAC for GOA other species (which includes squid) is set equal to 5 percent of the sum of all GOA groundfish TACs. Catches of other species in the GOA ranged between 1,570 mt and 6,867 mt from 1990 to 1999.

3.3.1.13 Forage Fish

Abundance, Distribution, and Food Habits

Forage fishes, as a group, occupy a nodal or central position in the North Pacific Ocean food web, being consumed by a wide variety of fish, marine mammals, and seabirds. Many species undergo large, seemingly unexplainable, fluctuations in abundance. Most of these are R-selected species (e.g., pollock, herring, Atka mackerel, capelin, sand lance), which generally have higher reproductive rates, are shorter-lived, attain sexual maturity at younger ages, and have faster individual growth rates than K-selected species (e.g., rockfish and many flatfish, which are species that are generally long-lived, reach sexual maturity at an older age, and grow slowly). Predators that utilize R-selected fish species as prey (marine mammals, birds, and other fish) have evolved in an ecosystem in which fluctuations and changes in relative abundance of these species have occurred. Consequently, most of them, to some degree, are generalists who are not dependent on the availability of a single species to sustain them, but instead rely on a suite of species, any one (or more) of which is likely to be abundant each year. However, differences in energy content exist among forage species, with herring, sand lance, and capelin containing higher energy content per unit mass than other forage species such as juvenile pollock (Payne et al. 1997). It is possible that changes in availability of higher energy content forage may influence growth and survival of the upper-trophic-level species reliant on forage species as their main prey.

Some evidence exists that osmerid abundance, particularly capelin and eulachon, have significantly declined since the mid-1970s. Evidence for this comes from marine mammal food habits data from the GOA (Calkins and Goodwin 1988), as well as from data collected in GOA biological surveys not designed to sample capelin (Anderson et al. 1997) and eastern Bering Sea commercial fisheries bycatch (Fritz et al. 1993). It is not known, however, whether smelt abundance has declined or whether the populations have redistributed vertically, presumably due to warming surface waters in the region beginning in the late 1970s. This conclusion could also be drawn from the data presented by Yang (1993), who documented considerable consumption of capelin by arrowtooth flounder, a demersal lower-water-column feeder, in the GOA.

Distribution, species associations, and biomass trends of various forage fishes in the Bering Sea were recently summarized by Brodeur et al. (1999). In addition to observations on the eastern shelf, this summary also included data from two Russian cruises that covered both eastern and western Bering Sea shelf regions in 1987. Spatial distributions of some forage species in the eastern Bering Sea (age 1 pollock, age 1 cod, Pacific herring, capelin, and eulachon) showed some spatial separation of the groups and some changes in distribution in a cold versus warm year. Capelin were associated with colder temperatures in the northern part of the study area, while age-0 pollock were associated with warmer temperatures than the overall measured temperature.

Eulachon were found only in the warmer temperatures at the southern part of the sampling area. Although this study did not find any long-term trends in forage fish abundance in the Bering Sea, the study period began in 1982, which is generally considered to be a warmer period in the Bering Sea. Analysis of 36 years of Russian pelagic trawl data indicates different periods of fish abundance, depending on environmental conditions. In the western Bering Sea and Okhotsk Sea, herring and capelin appear to alternate in abundance with pollock. Such a pattern has not been definitively identified for the eastern Bering Sea.

Smelts

Smelts (capelin, rainbow smelt, and eulachon, family Osmeridae) are slender schooling fishes that can be either marine, such as capelin (*Mallotus villasus*) or anadromous, such as rainbow smelt (*Osmerus mordax dentex*) and eulachon (*Thaleichthys pacificus*). Figure 3.3-9 shows a generalized distribution of these three smelt species in the southeastern Bering Sea based on data collected by NMFS summer groundfish trawl surveys and by fisheries observers.

Capelin are distributed along the entire coastline of Alaska and south along British Columbia to the Strait of Juan de Fuca. In the North Pacific Ocean, capelin can grow to a maximum of 25 cm at age 4. Most capelin spawn at age 2 or 3, when they are only 11 to 17 cm (Pahlke 1985). Spawning occurs in spring in intertidal

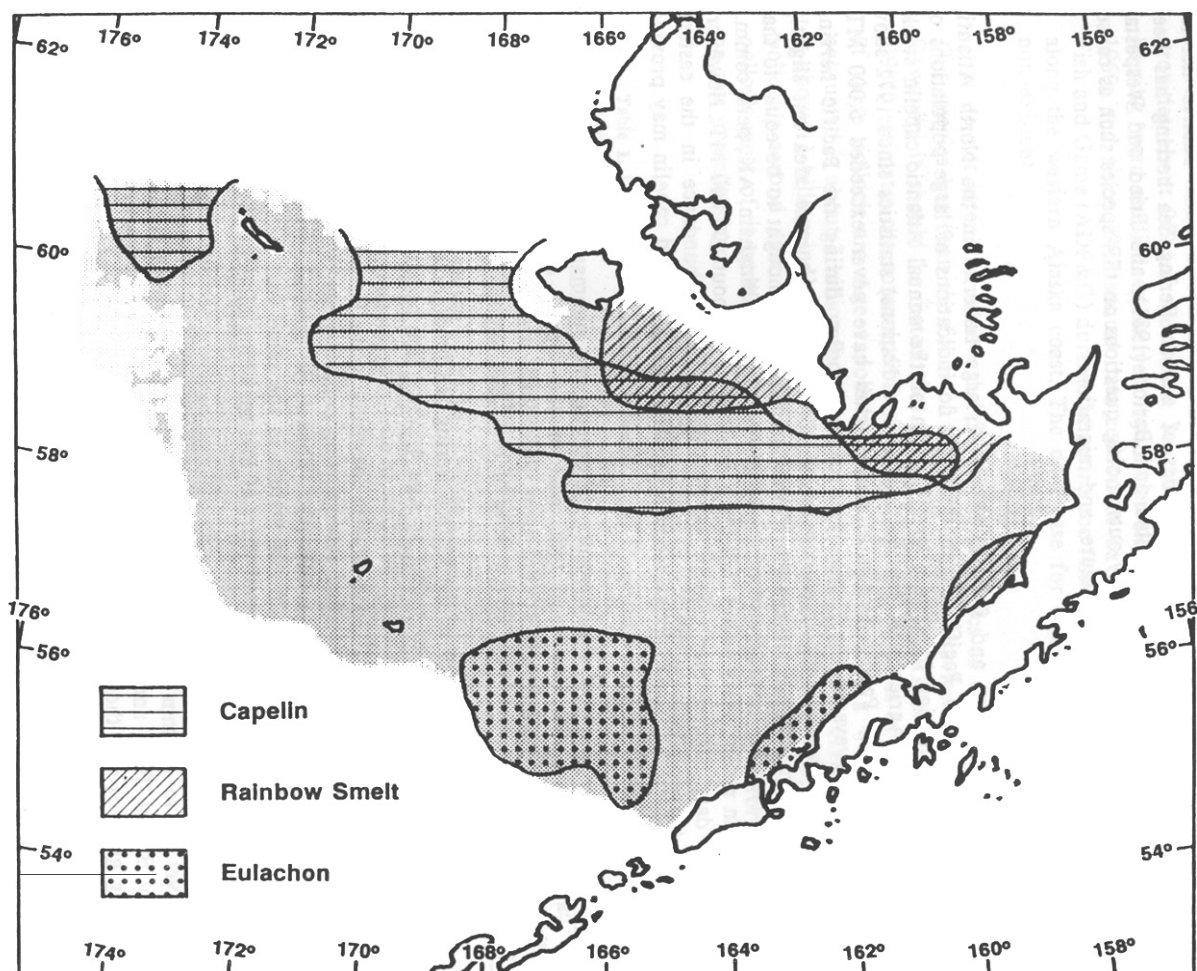


Figure 3.3-9 Distribution of capelin, rainbow smelt, and eulachon in Alaska Fisheries Science Center summer groundfish trawl surveys. Source: NMFS

zones of coarse sand and fine gravel—especially in Norton Sound, northern Bristol Bay, and around Kodiak Island. Very few capelin survive spawning. The age of maturity of capelin in the Barents Sea has been shown to be a function of growth rate, with fast-growing cohorts reaching maturity at an earlier age than slow-growing cohorts. Thus, it is possible to have slow- and fast-growing cohorts mature in the same year, resulting in large spawning biomasses one year preceded and potentially followed by small spawning biomasses.

In the Bering Sea, adult capelin are only found nearshore during the months surrounding the spawning run. During other times of the year, capelin are found far offshore in the vicinity of the Pribilof Islands and the continental shelf break. The seasonal migration may be associated with the advancing and retreating polar ice front, as it is in the Barents Sea. In the eastern Bering Sea, winter ice completely withdraws during the summer months. If migration follows the ice edge, the bulk of the capelin biomass in the Bering Sea could be located in the northern Bering Sea, beyond the area worked by the groundfish fisheries and surveys. Very few capelin are found in surveys, yet they are a major component of the diets of marine mammals feeding along the winter ice edge (Wespestad 1987), and of marine birds, especially in the spring. In the GOA, which remains ice-free-year-round, capelin overwinter in the bays of Kodiak Island and in Kachemak Bay.

Capelin have shown abrupt declines in occurrence in small-mesh trawl survey samples in the GOA (Piatt and Anderson 1996, Anderson and Piatt 1999). In both NMFS and ADF&G survey data, capelin first declined along the east side of Kodiak Island and bays along the Alaska Peninsula. Subsequent declines took place in the bays along the west side of Shelikof Strait. These declines happened quickly, and low abundance has persisted for over a decade. The decline was coincident with increases in water temperature of the order of 2°C, which began in the late 1970s. Capelin have fairly narrow temperature preferences and probably were very susceptible to the increase in water column temperatures (Piatt and Anderson 1996, Anderson et al. 1997). Mapping of relative densities of capelin showed defined areas of relative high abundance. The Shelikof Strait region showed relatively high catches in Kujulik, Alitak, and Olga bays. Most catches of capelin were closely associated with bays, except for of high catches offshore of Cape Ikolik at the southwest end of Kodiak Island. Isolated offshore areas east of Kodiak Island showed some high catches, with most of the high catches associated with Ugak and Kazakof Bays. Only isolated catches of less than 50 kg were evident in the database from Prince William Sound, the Kenai Peninsula, and lower Cook Inlet.

The diet of capelin in the North Pacific Ocean, as summarized by Hart (1973) and Trumble (1973), is primarily planktivorous. Small crustaceans such as euphausiids and copepods are common to the diet of capelin, although marine worms and small fish are also part of their diet. In the Bering Sea, adult capelin consume copepods, mysids, euphausiids, and chaetognaths. Juveniles primarily consume copepods (Naumenko 1984). The largest capelin (over 13 cm) consume euphausiids nearly exclusively. Capelin feed throughout the year in the Bering Sea. However, the diet exhibits seasonal variation that is due in part to spawning migration and behavior.

The primarily planktivorous diets of eulachon, sand lance, and capelin reduce the potential for dietary competition with the piscivorous and benthic diets of most groundfish. However, the potential for dietary competition is greater between pollock and forage fish due to the importance of planktonic prey, such as euphausiid and copepod in their diets.

Rainbow smelt ascend rivers to spawn in spring shortly after the ice breakup. After spawning, they return to the sea to feed. Surveys have found concentrations of rainbow smelt off Kuskokwim Bay, Togiak Bay, and Port Heiden (Figure 3.3-9), but they also probably occur near many river mouths. Rainbow smelt mature at ages 2 or 3 (19 to 23 cm), but can live to be as old as 9 years and as large as 30 cm. Little is known about abundance trends of this species.

Eulachon also spawn in spring in rivers of the Alaska Peninsula, and possibly other rivers draining into the southeastern Bering Sea. Eulachon live to age 5 and grow to 25 cm, but most die following their first spawning at age 3. Eulachon are consistently found by groundfish fisheries and surveys between Unimak Island and the Pribilof Islands in the Bering Sea, and in Shelikof Strait in the GOA (Figure 3.3-9). Evidence from fishery observer and survey data suggests that eulachon abundance declined in the 1980s (Fritz et al. 1993). These data should be interpreted with caution because surveys were not designed to sample small pelagic fishes such as eulachon, and fishery data were collected primarily to estimate total catch of target groundfish. Causes of the decline, if real, are unknown, but may be related to variability in year-class strength, as noted for capelin. Small-mesh shrimp trawl surveys in the GOA coastal areas suggest that eulachon has remained at a low level of relative abundance since 1987. Eulachon are currently at the lowest recorded level in the survey series (1972–1997) at 0.01 kg/km (Anderson and Piatt 1999).

The diet of eulachon in the North Pacific Ocean generally consists of planktonic prey (Hart 1973, Macy et al. 1978). As larvae they primarily consume copepod larvae; post-larvae consume a wider variety of prey, including phytoplankton, copepod eggs, copepods, mysids, ostracods, barnacle larvae, cladocerans worm larvae, and larval eulachon. Juvenile and adult eulachon feed almost exclusively on euphausiids, with copepods and cumaceans occasionally in the diet.

Pacific Sand Lance

Pacific sand lance (*Ammodytes hexapterus*, family Ammodytidae) are usually found on the sea bottom, at depths between 0 and 100 m except when feeding (pelagically) on crustaceans and zooplankton. Spawning is believed to occur in winter. Sand lance mature at 2 to 3 years and lengths of 10 to 15 cm. Little is known of their distribution and abundance; they are rarely caught by trawls. In the Bering Sea, sand lance are common prey of salmon, northern fur seals and many marine bird species. Thus, they may be abundant in Bristol Bay and along the Aleutian Islands and Alaska Peninsula. In the GOA, sand lance are prey of harbor seals, northern fur seals, and marine birds, especially in the Kodiak Island area and along the southern Alaska Peninsula. Given the sand lance's short life span, and the large number of species that prey on it, mortality, fecundity, and growth rates are probably high.

Sand lance in the Kodiak Island region undergo an extensive migration that is counter to the normal pattern found with many inshore species. Spawning takes place in the late fall and winter, and usually is completed in January. Hatching of larvae continues over an extended time, until March and perhaps April (Blackburn et al. 1983, Blackburn and Anderson 1997), and some larval fish may spend up to several months in beach sediments. Newly hatched larval sand lance and adults start migrating offshore in the early spring and spend some time in offshore bank areas, where they can often be abundant (Clemens and Willoughby 1961). Offshore ichthyoplankton surveys in the GOA indicated high larval abundance, first appearing in early March and remaining high until early July, but then disappearing. In the late summer, massive schools of fish start migrating inshore to suitable beach habitat for spawning and overwintering. These inshore migrating schools provide important forage for species such as offshore migrating seabirds during late summer and early fall. Hence, sand lance are among one of the few fish that migrate inshore during the late summer months to overwinter near-shore while most other fish migrate offshore prior to winter months.

Hart (1973) and Trumble (1973) summarized the diet of sand lance in the North Pacific Ocean as primarily planktivorous; their primary prey changing with ontogeny. Larval sand lance consume diatoms (microscopic one-celled or colonial algae) and dinoflagellates (photosynthetic marine organisms); post-larvae prey upon copepods and copepod nauplii. More recent information on the food habits of age-0 and age-1 sand lance show a dominance of calanoid copepods in the diet, with barnacle nauplii, larvaceans, and shrimp larvae as other important prey (Blackburn and Anderson 1997). Adult sand lance prey upon chaetognaths, fish larvae,

amphipods, annelids, and common copepods. Sand lance exhibit seasonal and diurnal variation in feeding activity and are opportunistic feeders upon abundant plankton blooms.

Lantern Fish and Deep-sea Smelt

Lantern fishes (family Myctophidae) and deep-sea smelts (family Bathylagidae) are distributed pelagically in the deep sea throughout the world's oceans. Most species in both families occur at depth during the day and migrate to near the surface to feed (and be fed upon) at night. A common myctophid in the Bering Sea and GOA is the northern lampfish (*Stenobrachius leucopsarus*), which has a maximum length of approximately 13 cm. Deep-sea smelt of the North Pacific Ocean include blacksmelt (*Bathylagus* spp.) and northern smoothtongue (*Leuroglossus stilbius schmidtii*), each of which have maximum lengths of 12–25 cm. Lanternfish and deep-sea smelt are important forage fishes for marine birds and mammals. Because they are rarely caught in survey or fishery trawls, nothing is known of recent trends in their abundance.

Because deep-sea smelts have a small mouth, dense flat gill rakers, a small stomach, and long intestine, they consume weak-swimming, soft-bodied animals such as pteropods, appendicularia, ctenophores, chaetognaths, polychaetes, and jellyfishes. Deep-sea smelts in the epipelagic zone can also feed on euphausiids and copepods at night when they are abundant (Balanov et al. 1995, Gorelova and Kobylanskiy 1985).

Because of their large mouth, relatively sparse and denticulate gill rakers, well-developed stomach, and short intestine, lantern fishes mostly consume actively swimming animals such as copepods and euphausiids (Balanov et al. 1995).

Pacific Sandfish

The Pacific sandfish (*Trichodon trichodon*, family Trichodontidae) lives in shallow inshore waters to about 50 m depth and grows to a maximum length of 30 cm. Some evidence shows sandfish exhibit burrowing behavior in which they bury themselves in the sand and come to rest with only their dorsal surface showing. Nothing is known of trends in their abundance. They are fed upon by salmon and other fish, as well as pinnipeds.

The diet of sandfish consists of small crustaceans such as mysids, amphipods, and cumaceans (Kenyon 1956, Mineva 1955). More recent information from the GOA shows that sandfish consume sand lance, several types of shrimp, crab larvae, cumaceans, and polychaetes (Paul et al. 1997). In the eastern Bering Sea, the diet of Pacific sandfish is primarily (95 percent by weight) fish, especially gadids (Brodeur and Livingston 1988).

Euphausiids

Along with many copepod species, the euphausiids form a critical zooplanktonic link between the primary producers (phytoplankton) and all upper pelagic trophic levels. These crustaceans, also known as krill, occur in large swarms in both neritic (nearshore) and oceanic (offshore) waters. Members of at least 11 genera of euphausiids are known from the North Pacific Ocean, the most important (in terms of numbers of species) being *Thysanopoda*, *Euphausia*, *Thysanoëssa*, and *Stylocheiron* (Boden et al. 1955, Ponomareva 1963). Euphausiids are generally thought to make diurnal vertical migrations, remaining at depth (usually below 500 m) during the day and ascending at night to 100 m or less to feed. However, this is complicated by the fact that as euphausiids grow they are found at deeper depths, except during spawning, which occurs in surface waters. Spawning occurs in spring to take advantage of the spring phytoplankton bloom, and the hatched nauplii larvae live near the surface (down to about 25 m). By fall and winter, the young crustaceans are found mainly at depths of 100 m or less, and make diurnal vertical migrations. Sexual maturity is reached the following spring

at age 1. After spawning, a dult euphausiids gradually descend to deeper depths until fall and winter, when they no longer migrate daily to near-surface waters. In their second spring, they again rise to the surface to spawn; euphausiids older than 2 years are very rarely found. This classical view of euphausiid life history and longevity was recently questioned by Nichol (1990), who reported that Antarctic euphausiids may live as long as 6 to 10 years; annual euphausiid production, then, would be much lower than if they lived only 2 years.

While euphausiids are found throughout oceanic and neritic waters, their swarms are most commonly encountered in areas where nutrients are available for phytoplankton growth. This occurs primarily in areas where upwelling of waters from depths into the surface region is a consistent oceanographic feature. Areas with such features are at the edges of the various domains on the shelf or at the shelf-break, at the heads of submarine canyons, on the edges of gullies on the continental shelf (e.g., Shumagin, Barnabus, Shelikof gullies in the GOA), in island passes (on certain tides) in the Aleutian Islands (e.g., Seguam Pass, Tanaga Pass), and around submerged seamounts (e.g., west of Kiska Island). It is no coincidence that these are also prime fishing locations used by commercial fishing vessels seeking zooplanktivorous groundfish, such as pollock, Atka mackerel, sablefish, and many rockfish and flatfish species (Fritz et al. 1993, Livingston and Goiney 1983, Yang 1993).

The species comprising the euphausiid group occupy a position of considerable importance within the North Pacific Ocean food web. Euphausiids are eaten by almost all other major taxa inhabiting the pelagic realm. The diet of many fish species other than the groundfish listed previously—including salmon, smelt (capelin, eulachon, and other osmerids), gadids such as Arctic cod and Pacific tomcod, and Pacific herring—is composed, to varying degrees, of euphausiids (Livingston and Goiney 1983). They are also the principal item in the diet of most baleen whales (e.g., minke, fin, sei, humpback, northern right, and bowhead whales [Perez 1990]). While copepods generally constitute the major portion of the diet of planktivorous birds (e.g., auklets), euphausiids are prominent in the diets of some predominately piscivorous birds in certain areas [e.g., kittiwakes on Buldir Island in the Aleutian Islands, Middleton Island in the GOA, and Saint Matthew Island in the Bering Sea (Hatch et al. 1990)]. Euphausiids are not currently sought for human use or consumption from the North Pacific Ocean on a scale other than local, but large (about 500,000 mt per year) krill fisheries from Japan and Russia have been operating in Antarctic waters since the early 1980s (Swartzman and Hofman 1991).

The diets of euphausiids in the North Pacific Ocean consist of planktonic prey. Species of the genus *Euphausia* consume diatoms, dinoflagellates, tintinnids, chaetognaths, echinoderm larvae, amphipods, crustacean larvae, ommatidians, and detritus (Mauchline 1980). Species of the genus *Thysanoessa* consume diatoms, dinoflagellates, tintinnids, radiolarians, foraminiferans, chaetognaths, echinoderm larvae, mollusks, crustacean larvae, ommatidians and detritus (Mauchline 1980). In the GOA, several species of *Thysanoessa* also consume walleye pollock eggs (Brodeur and Merati 1993).

Gunnels and Pricklebacks

Gunnels (family Pholidae) and pricklebacks (family Stichaeidae, including warbonnets, eelblennys, cockscombs and shannys) are long, compressed, eel-like fishes with long dorsal fins often joined with the caudal fin. Pricklebacks are so named because of the spiny rays in the dorsal fin in most species (some have soft rays at the rear of the dorsal fins). Gunnels have flexible dorsal fin rays; they differ from pricklebacks in that the anal fin is smaller (the distance from the tip of the snout to the front of the anal fin is shorter than the length of the anal fin). Most species of both families live in shallow nearshore waters among seaweed and under rocks and are mostly less than 45 cm in length. Approximately 14 species of stichaeids and 5 species of pholids occur in Alaska. Nothing is known about their abundance, and little is known about growth rates, maturity, and trophic relationships, although they are believed to grow quickly. Some cockscombs in British Columbia attain sexual maturity at age 2 years.

The diets of gunnels (family Pholidae) consist primarily of benthic and epibenthic prey. Amphipods, isopods, polychaete worms, harpacticoid copepods, cumaceans, mud crabs, insects, mysids, algae, ostracods, bivalves, crustacean larvae, and tunicates have been described as their main prey (Simenstad et al. 1979, Williams 1994). Juvenile fish prey (English sole, *Parophrys vetulus*, and sand lance, *Ammodytes hexapterus*) have also been described as infrequent components of its diet in Puget Sound, Washington (Simenstad et al. 1977).

Some of the diets of the stichaeids are described here. The longsnout pricklyback (*Lumpenus longirostris*) eats copepods almost exclusively (Barraclough 1967). Young ribbon pricklybacks (*Phytichthys chirus*) eat copepods and oikopleura (Robinson et al. 1968). The food of the adults of this species includes crustaceans and red and green algae. Black pricklybacks (*Xiphister atropurpureus*) consume copepods, copepod nauplii, and clam larvae (Barraclough et al. 1968). It has also been reported that an important food of high cockscomb (*Anoplarchus purpureus*) was green algae. Other food of this species include polychaete worms, amphipods, mollusks, and crustaceans.

Bristlemouths, Lightfishes, Anglemouths

This is a large and diverse family (Gonostomatidae) of small (to about 8 cm), bathypelagic fish that are rarely observed except by researchers. They can be abundant at depths of up to 5,000 m. As many as six species may occur in the North Pacific Ocean and Bering Sea.

Bristleworms, lightfishes, and anglemouths (Gonostomatidae) have large gill openings and well-developed gill rakers, characteristics of zooplankton feeders. The primary zooplankton prey of gonostomatids are calanoid copepods. Other food includes ostracods and euphausiids. Some larger gonostomatids also consume some fish (Gorelova 1980).

Significance of Forage Fish in the Diet of Eastern Bering Sea Groundfish

In the eastern Bering Sea, forage fish, as defined here, are found in the diets of walleye pollock, Pacific cod, arrowtooth flounder, Pacific halibut, Greenland halibut, yellowfin sole, rock sole, Alaska plaice, flathead sole, and skates. However, forage fish do not represent a large portion of the diet, by weight, of these predators, with the exception of shelf rock sole (14.3 percent) and slope pollock (12.6 percent). Tables 3.3-2 and 3.3-3 present the ten most important prey, by weight, in the diets of each predator for the eastern Bering Sea shelf and slope regions, respectively. All forage fish species are italicized. Forage fish that are in the diet, but not one of the ten most important prey by weight, are also listed. The miscellaneous fish category represents all fish prey not included as one of the ten most important prey categories, primarily unidentified fish. All groundfish diet data are from the Alaska Fisheries Science Center's Resource Ecology Fishery Management Division, groundfish food habits database.

Eastern Bering Sea Shelf

Despite the generally piscivorous diet of cod, arrowtooth flounder, Pacific halibut, Greenland halibut, and skates, forage fish are not principal components, by weight, in the diets of eastern Bering Sea groundfish (Table 3.3-2). Sand lance are the most prevalent forage fish in the diet of cod (0.8 percent) while capelin, osmerids, bathylagids, myctophids, and eulachon each represent 0.1 percent or less of the diet by weight. In the diet of arrowtooth flounder, capelin and eulachon each represent 0.2 percent of the diet by weight, while osmerids,

Table 3.3-2 The Diet of Selected Eastern Bering Sea Shelf Groundfish Species

Rank	Pollock	Cod	Arrowtooth Flounder	Pacific Halibut	Greenland Halibut
1	Euphausiids (44.9)	Pollock (49.1)	Pollock (67.4)	Pollock (53.9)	Pollock (74.8)
2	Pollock (17.0)	Offal (12.1)	Miscellaneous fish (15.3)	Flatfish (9.0)	Squid (11.1)
3	Copepods (11.4)	Brachyuran crab (10.3)	Herring (5.4)	Brachyuran crabs (7.8)	Miscellaneous fish (6.2)
4	Shrimp (8.0)	Miscellaneous fish (7.6)	Offal (3.6)	Misc. fish (7.6)	Offal (4.1)
5	Amphipods (4.1)	Flatfish (7.1)	Amphipods (1.8)	Anomuran crabs (4.6)	Flatfish (1.2)
6	Mysids (3.2)	Anomuran crabs (3.4)	Squid (1.8)	Cod (4.3)	Cod (0.9)
7	Miscellaneous fish (2.8)	Shrimp (2.5)	Euphausiids (1.5)	Offal (4.1)	Herring (0.7)
8	Offal (1.1)	Polychaete worms (1.0)	Flatfish (1.0)	<i>Sand lance</i> (2.2)	<i>Myctophids</i> (0.2)
9	<i>Capelin</i> (0.7)	<i>Sand lance</i> (0.8)	Scorpaenids (0.3)	<i>Capelin</i> (1.8)	Shrimp (0.2)
10	<i>Sand lance</i> (0.5)	Gastropods (0.5)	<i>Capelin</i> (0.2)	Herring (1.1)	Cyclopterids (0.2)
Other forage fish	<i>Osmerids</i> (<0.1) <i>Bathylagids</i> (<0.1) <i>Myctophids</i> (<0.1) <i>Eulachon</i> (<0.1)	<i>Capelin</i> (0.1) <i>Osmerids</i> (<0.1) <i>Bathylagids</i> (<0.1) <i>Myctophids</i> (<0.1) <i>Eulachon</i> (<0.1)	<i>Eulachon</i> (0.2) <i>Osmerids</i> (0.1) <i>Myctophids</i> (<0.1) <i>Sand lance</i> (<0.1)	<i>Osmerids</i> (0.1) <i>Eulachon</i> (<0.1)	<i>Bathylagids</i> (0.1) <i>Osmerids</i> (<0.1) <i>Sand lance</i> (<0.1)
Rank	Yellowfin Sole	Rock Sole	Alaska Plaice	Flathead Sole	Skates
1	Echiuroid worms (22.4)	Polychaete worms (44.9)	Polychaete worms (55.5)	Echinoderms (28.3)	Pollock (56.7)
2	Bivalves (18.5)	<i>Sand lance</i> (14.3)	Bivalves (11.1)	Pollock (25.6)	Miscellaneous fish (9.9)
3	Polychaete worms (18.1)	Echiuroid worms (11.0)	Echiuroid worms (10.7)	Shrimp (12.8)	Brachyuran crabs (8.8)
4	Amphipods (7.0)	Amphipods (7.2)	Sipunculid worms (10.7)	Miscellaneous fish (5.8)	Flatfish (6.7)
5	Echinoderms (3.7)	Bivalves (5.1)	Amphipods (4.6)	Euphausiids (4.5)	Shrimp (5.5)
6	Anomuran crabs (3.7)	Sipunculid worms (5.0)	Priapulid worms (2.8)	Offal (3.9)	Offal (5.2)
7	Euphausiids (3.2)	Echinoderms (2.8)	Echinoderms (2.0)	Mysids (3.5)	Anomuran crabs (3.1)
8	Shrimp (3.1)	Shrimp (2.0)	Unidentified crustaceans (0.6)	Bivalves (3.1)	Amphipods (1.3)
9	Gastropods (2.6)	Miscellaneous fish (1.6)	<i>Sand lance</i> (0.5)	Anomuran crab (2.5)	<i>Sand lance</i> (0.7)
10	Brachyuran crabs (2.4)	Priapulid worms (1.5)	Brachyuran crabs (0.2)	Brachyuran crab (2.3)	Cod (0.4)
Other forage fish	<i>Sand lance</i> (0.6) <i>Bathylagids</i> (<0.1) <i>Capelin</i> (<0.1)	<i>Osmerids</i> (<0.1)	N/A	<i>Capelin</i> (1.3) <i>Sand lance</i> (0.5) <i>Osmerids</i> (0.1) <i>Myctophids</i> (<0.1)	<i>Capelin</i> (0.1) <i>Sandfish</i> (0.1) <i>Myctophids</i> (<0.1)

Notes: Forage fish in the diet appear in italics.
Numbers in parentheses represent percent by weight contribution to the diet.
N/A – Indicates no other forage fish in the diet.
Source: NMFS, unpublished data

myctophids, and sand lance each constitute 0.1 percent or less. The diet of Pacific halibut contains 2.2 percent sand lance and 1.8 percent capelin; osmerids and eulachon each represent 0.1 percent or less. Myctophids represent 0.2 percent of the diet of Greenland turbot; bathylagids, osmerids, and sand lance represent 0.1 percent or less. Sand lance are the most important forage fish in the diet of skates (0.7 percent); capelin, sandfish, and myctophids each represent 0.1 percent or less. Sand lance is the most prevalent forage fish species in the diet of walleye pollock (0.5 percent); osmerids, bathylagids, myctophids, and eulachon each represent less than 0.1 percent of the diet by weight. The total contribution (0.6 percent) of forage fishes to the diet of yellowfin sole is primarily due to sand lance; bathylagids and capelin each represent less than 0.1 percent by weight. Sand lance are the second most important prey in the diet of rock sole, 14.3 percent by weight; osmerids are the only other forage fish present in the diet (less than 0.1 percent). Sand lance are the only forage fish found in the diet of Alaska plaice, representing 0.5 percent of the diet. Flathead sole consume capelin (1.3 percent), sand lance (0.5 percent), osmerids (0.1 percent) and myctophids (less than 0.1 percent).

Eastern Bering Sea Slope

Lang and Livingston (1996) studied the diets of groundfish in the eastern Bering Sea slope region. In this region, forage fish are relatively unimportant in the diets of Greenland halibut, flathead sole, arrowtooth flounder, and cod (Table 3.3-3). However, 12.6 percent of the diet of pollock on the slope consists of forage fishes. Greenland halibut consume bathylagids (0.4 percent) and myctophids (0.4 percent) as the only forage fish in their diet. Flathead sole also consumed bathylagids (0.3 percent) and myctophids (0.1 percent). Myctophids (0.2 percent) are the only forage fish found in the diet of arrowtooth flounder. Pollock consume bathylagids (7.0 percent), myctophids (5.5 percent), osmerids (0.1 percent), and sand lance (less than 0.1 percent). Forage fish are negligible in the diet of cod; bathylagids represent less than 0.1 percent of the diet by weight.

Significance of Forage Fish in the Diet of Gulf of Alaska Groundfish

Yang and Nelson (2000) studied the diets of groundfish in the GOA shelf during summer. They found that the main fish prey of groundfish in the GOA included pollock, Pacific herring, capelin, Pacific sand lance, eulachon, Atka mackerel, bathylagids, and myctophids (Table 3.3-4). Although walleye pollock was the most important fish prey of arrowtooth flounder, Pacific halibut, sablefish, Pacific cod, and walleye pollock in the GOA, other forage fish species comprised 1 to 23 percent of the diet of groundfish. Capelin was important food of arrowtooth flounder and pollock, comprising 23 and 7 percent of the diet of arrowtooth flounder and walleye pollock in 1990, respectively. The consumption of the capelin by walleye pollock gradually decreased to 3 percent in 1993; to 0 percent in 1996. Compared to 1990, arrowtooth flounder also consumed less capelin in 1993 (4 percent) and in 1996 (10 percent). The capelin consumed by these groundfish were mainly located northeast and southwest of Kodiak Island. Eulachon comprised 6 percent of the food of sablefish. Myctophids were important forage fish for shortraker rockfish, comprising 18 percent of the diet of shortraker rockfish. Pacific sand lance were found in the stomachs of arrowtooth flounder, Pacific halibut, sablefish, Pacific cod, and walleye pollock, but their contribution to these diets was small (1 percent or less). Bathylagids were only found in the diet of walleye pollock, and they contributed less than 1 percent. Pacific sandfish was not found in the diet of the groundfish in the GOA.

In the Atlantic, strong interactions between cod and capelin have been recorded (Akenhead et al. 1982). Even though Pacific cod did not feed so heavily on capelin in the GOA, capelin was an important fish prey of several groundfish species. The distribution and the abundance of forage fish in the GOA are not well known. However, a series of years with poor forage fish recruitment, which decreases the availability of small prey fish, may have greater impact on piscivorous groundfishes.

Table 3.3-3 Diet of Selected Eastern Bering Sea Slope Groundfish Species

Rank	Greenland Halibut	Flathead Sole	Arrowtooth Flounder	Pollock	Cod
1	Pollock (58.3)	Echinoderm (49.6)	Pollock (55.4)	Euphausiids (26.4)	Pollock (51.4)
2	Squid (18.5)	Offal (23.7)	Miscellaneous fish (15.9)	Shrimp (16.4)	Offal (9.7)
3	Offal (11.9)	Scorpaenidae (10.1)	Squid (11.3)	Pollock (15.8)	Miscellaneous fish (9.1)
4	Miscellaneous fish (5.0)	Shrimp (4.2)	Herring (11.1)	Squid (8.3)	Shrimp (8.6)
5	Cyclopterids (2.7)	Miscellaneous fish (4.0)	Shrimp (4.6)	Miscellaneous fish (7.0)	Brachyuran crab (6.2)
6	Flatfish (0.8)	Pollock (2.9)	Offal (0.7)	<i>Bathylagids</i> (7.0)	Flatfish (4.0)
7	Herring (0.6)	Polychaete worms (1.6)	Echinoderm (0.3)	<i>Myctophids</i> (5.5)	Herring (3.5)
8	<i>Bathylagids</i> (0.4)	Brachyuran crab (1.4)	Miscellaneous Unidentified (0.3)	Offal (3.7)	Squid (1.9)
9	<i>Myctophids</i> (0.4)	Squid (0.4)	Euphausiids (0.2)	Copepods (2.2)	Cod (1.0)
10	Anomuran crab (0.1)	Mysid (0.4)	<i>Myctophids</i> (0.2)	Herring (2.5)	Polychaete worms (0.9)
Other forage fish	N/A	<i>Myctophids</i> (0.3) <i>Bathylagids</i> (0.1)	N/A	<i>Osmerids</i> (0.1) <i>Sand lance</i> (<0.1)	<i>Bathylagids</i> (<0.1)

Notes: Forage fish in the diet appear in italics.
Numbers in parentheses represent percent by weight contribution to the diet.
N/A – Indicates no other forage fish in the diet.
Source: Lang and Livingston 1996

Table 3.3-4 Percent by Weight of Important Prey Consumed by Groundfish in the Gulf of Alaska

Prey	Predator										
	Arrowtooth Flounder	Pacific Halibut	Sablefish	Pacific Cod	Pollock	Shortspine Thornyhead	Rougheye Rockfish	Shortraker Rockfish	Dusky Rockfish	Pacific Ocean Perch	Northern Rockfish
Pollock	66	57	24	7	2	1	0	0	0	0	0
Herring	9	0	2	-	-	0	0	0	0	0	0
Capelin	8	1	-	2	13	1	0	0	0	0	0
Pacific sand lance	-	1	-	-	-	0	0	0	0	0	0
Eulachon	1	-	6	-	0	0	0	0	0	0	0
Atka mackerel	1	0	0	0	0	0	0	0	0	0	0
Bathylagid	0	0	0	0	-	0	0	0	0	0	0
Myctophid	0	0	-	0	0	0	0	18	0	1	0
Tanner crab	0	6	-	12	0	1	2	0	0	-	-
Pandalids	4	-	4	9	19	54	51	0	4	2	0
Cephalopods	2	5	8	10	3	1	21	82	6	1	-
Offal	1	7	29	13	0	0	0	0	0	0	0
Euphausiids	3	0	7	1	39	0	2	0	69	87	96
Calanoid copepods	0	0	0	0	1	0	0	0	2	2	3

Notes: - means less than 1 percent

Source: Yang and Nelson 2000

The Significance of Forage Fish in the Diet of Aleutian Islands Groundfish

Yang (1996) studied the diets of groundfish in the Aleutian Islands during summer. He found that main fish prey of groundfish in the Aleutian Islands included Atka mackerel, walleye pollock, Pacific herring, capelin, myctophids, bathylagids, Pacific sand lance, and eulachon (Table 3.3-5). Although Atka mackerel and walleye pollock were important fish prey of arrowtooth flounder, Pacific halibut, and Pacific cod, other forage fish species comprised from 1 to 37 percent of groundfish diets. Most of the Atka mackerel consumed by the groundfish were located near Attu, Agattu, Amchitka, Tanaga, Atka, and Unalaska Islands. Myctophids were an important forage fish. Large amounts of myctophids were found in the diets of Greenland turbot, walleye pollock, Pacific ocean perch, and shortraker rockfish. They were also found in arrowtooth flounder, Pacific cod, rougheye rockfish, Atka mackerel, and northern rockfish. Most myctophids consumed by the groundfish were located near Kiska, Adak, Seguam, and Yunaska Islands. It is notable that nine out of eleven groundfish species shown in Table 3.3-5 consumed myctophids as food. If the abundance of the myctophids declines dramatically, it could impact the growth of Aleutian Islands groundfish, which depend on myctophids for a main food resource. Bathylagids were found in the diets of Greenland turbot and walleye pollock. Capelin were found in the diet of Pacific halibut and walleye pollock collected in the Akutan Island area, but they contributed only 5 percent and less than 1 percent of the diets of Pacific halibut and walleye pollock, respectively. Pacific sand lance were food of arrowtooth flounder, Pacific halibut, Pacific cod, and walleye pollock, but they contributed less than 1 percent of these diets. Only a small amount (less than 1 percent) of eulachon was found in the diet of walleye pollock. Pacific sandfish was not found in the diets of the groundfish in the Aleutian Islands area.

Forage Fish in the Diets of Eastern Bering Sea, Gulf of Alaska, and Aleutian Islands Groundfish

Euphausiids

Euphausiids (Euphausiacea) represent a significant portion of the diet of walleye pollock in the eastern Bering Sea shelf region (Livingston 1991a). Euphausiids represent as much as 70 percent of the diet in the winter and spring and are generally more important to larger pollock than smaller ones. Euphausiids are also the primary prey of small (less than 35 cm) Greenland turbot in the eastern Bering Sea shelf, but are of little importance to larger fish (Livingston and DeReynier 1996). Small (less than 35 cm) arrowtooth flounder also consume euphausiids as a large (50 percent by weight) portion of their diet; euphausiids are of little importance to the larger ones (Livingston and DeReynier 1996). Euphausiids were not found to a significant diet component of any other eastern Bering Sea shelf groundfish. In the eastern Bering Sea slope region, euphausiids were found in the diets of several groundfish species. They represent 26 percent of the overall diet by weight of walleye pollock, but are more important by season (80 percent by weight in winter) and to smaller (less than 50 cm) fish (Lang and Livingston 1996). Euphausiids also play a small role (less than 1 percent by weight) in the diets of Pacific cod, flathead sole, and arrowtooth flounder (Lang and Livingston 1996).

Euphausiids are an important food item of many groundfish species in the GOA and Aleutian Islands. Yang (1993) showed that the diets of plankton-feeding groundfish in the GOA, such as dusky rockfish, Pacific ocean perch, and northern rockfish had large percentages (more than 65 percent) of euphausiids. Euphausiids also comprised 39 percent of the diet of walleye pollock in the GOA. In the Aleutian Islands, euphausiids also comprised 43, 55, 51, and 50 percent of the stomach contents of walleye pollock, Atka mackerel, Pacific ocean perch, and northern rockfish, respectively. Euphausiids were also in the diets of arrowtooth flounder (5 percent), rougheye rockfish (2 percent), shortspine thornyhead (1 percent), and shortraker rockfish (1 percent) in the Aleutian Islands (Yang 1996).

Table 3.3-5 Percent by Weight of Important Prey Consumed by Groundfish in the Aleutian Islands

Prey	Predator										
	Arrowtooth Flounder	Pacific Halibut	Pacific Cod	Greenland Turbot	Pollock	Shortspine thornyhead	Rougeye Rockfish	Shortraker Rockfish	Atka Mackerel	Pacific Ocean Perch	Northern Rockfish
Atka mackerel	44	12	27	0	0	0	0	0	0	0	0
Pollock	13	19	17	1	0	0	0	0	2	0	0
Herring	-	2	1	0	0	0	0	0	0	0	0
Capelin	0	5	0	0	-	0	0	0	0	0	0
Myctophid	7	0	3	28	37	0	4	15	1	34	1
Bathylagid	0	0	-	13	1	0	0	0	0	0	0
Pacific sand lance	-	-	-	0	-	0	0	0	0	0	0
Eulachon	0	0	0	0	-	0	0	0	0	0	0
Tanner crab	0	7	2	0	-	0	0	0	-	0	0
Cottid	3	1	7	0	-	51	0	19	-	0	0
Cyclopterid	-	-	-	0	-	1	45	0	0	0	0
Shrimp	2	-	10	0	4	23	45	32	-	0	3
Cephalopods	3	27	12	50	2	-	0	3	8	2	1
Euphausiids	5	-	-	0	43	1	2	1	55	51	50
Calanoid copepods	-	0	-	0	3	0	0	0	17	7	17

Notes: - means less than 1 percent

Source: Yang 1996

Stichaeids

Stichaeids represent a minimal portion of the diets of several groundfish species in the eastern Bering Sea shelf region. Pacific cod (Livingston 1991b), arrowtooth flounder (Yang 1996), and flathead sole (Pacunski 1991) consume unidentified stichaeids as less than 1 percent of their diets by weight. Greenland turbot consume a combination of unidentified stichaeids and daubed shanny (*Lumpenus maculatus*) as a small portion (less than 1 percent) of their diet.

Stichaeids represent a small portion (less than 1 percent by weight) of the diet of Pacific cod, arrowtooth flounder, and Greenland turbot in the eastern Bering Sea slope region (Lang and Livingston 1996). Yang (1993) who studied the diets of the groundfish in the GOA during summer, found that stichaeids comprised about 1 percent of the stomach content weight of arrowtooth flounder, Pacific cod, and walleye pollock, respectively. Pacific halibut, sablefish, and Pacific ocean perch also consumed stichaeids, but their contribution to the diets was small (less than 1 percent). Yang (1996) also studied the diets of groundfish in the Aleutian Islands. He found that stichaeids comprised 2 percent of the stomach contents weight of arrowtooth flounder. Stichaeids comprised less than 1 percent of the diets of Pacific cod, walleye pollock, and Atka mackerel.

Gonostomatids

Gonostomatids were not found to be a significant portion of the diets of eastern Bering Sea shelf or slope groundfish (Livingston and DeReynier 1996). Gonostomatids are probably not important prey of GOA groundfish because they were not found in a study of groundfish diets in that area (Yang 1993). However, they were found in pollock stomachs in the Aleutian Islands, but contributed less than 1 percent by weight of the total stomach content (Yang 1996).

Pholids

Pholids (saddleback gunnel) were found in Pacific cod stomachs in the Aleutian Islands, but their contribution was less than 1 percent by weight of the total stomach content. Pholids were not found as a significant portion of the diets of eastern Bering Sea shelf or slope groundfish. Pholids are probably not important prey of the GOA groundfish area because they were not found in a study of groundfish diets in that area (Yang 1993).

Significance of Forage Fish to Seabirds

Capelin and sand lance are crucial to many bird species; other forage fish include myctophids, herring, Pacific saury, and pollock (Tables 3.3-6 and 3.3-7). Many seabirds can subsist on a variety of invertebrates and fish during nonbreeding months, but can only raise their nestlings on forage fish (Sanger 1987a, Vermeer et al. 1987). Refer to Section 3.5 for further details about seabirds.

Seabird population trends throughout the Arctic and subarctic are largely determined by forage fish availability (Birkhead and Furness 1985). Lack of prey usually causes population declines through breeding failure rather than adult mortality. Although seabirds can adapt to occasional years of poor food and reproduction, a long-term scarcity of forage fish leads to population declines. Reproductive success in Alaskan seabirds is strongly linked to the availability of appropriate fish. Breeding failure as a result of forage fish scarcity has been documented in Alaska for black-legged kittiwakes, glaucous-winged gulls (*Larus glaucescens*), pigeon guillemots (*Cepphus columba*), and murrelets (Baird 1990, Kuletz 1983, Murphy et al. 1987, Murphy et al. 1984, Springer 1991a). Similar observations have been made for seabirds in British Columbia (Vermeer et al. 1979, Vermeer and Westerheim 1984) and the North Atlantic (Barrett et al. 1987, Brown and Nettleship 1984, Harris and Hislop 1978, Monaghan et al. 1989, Vader et al. 1990). Breeding failure can result when

Table 3.3-6 Estimated Populations and Principal Diets of Seabirds that Breed in the Bering Sea, Aleutian Islands, and Gulf of Alaska

Species	Population ^{a, b}		Diet ^{c, d}
	BSAI	GOA	
Northern fulmar (<i>Fulmarus glacialis</i>)	1,500,000	600,000	Q,M,F,Z,I
Fork-tailed storm-petrel (<i>Oceanodroma furcata</i>)	4,500,000	1,200,000	Z,Q,C
Leach's storm-petrel (<i>Oceanodroma leucorhoa</i>)	4,500,000	1,500,000	Z,Q
Double-crested cormorant (<i>Phalacrocorax auritus</i>) ^e	9,000	8,000	F,I
Pelagic cormorant (<i>Phalacrocorax pelagicus</i>)	80,000	70,000	S,C,P,H,F,I
Red-faced cormorant (<i>Phalacrocorax urile</i>)	90,000	40,000	C,S,H,F,I
Brandt's cormorant (<i>Phalacrocorax penicillatus</i>)	0	100	?
Pomarine jaeger (<i>Stercorarius pomarinus</i>)	Common	Common	C,S
Parasitic jaeger (<i>Stercorarius parasiticus</i>)	Common	Common	C,S
Long-tailed jaeger (<i>Stercorarius longicaudus</i>)	Common	Common	C,S
Bonaparte's gull (<i>Larus philadelphia</i>)	Rare	Common	?
Mew gull (<i>Larus canus</i>) ^e	700	40,000	C,S,I,D
Herring gull (<i>Larus argentatus</i>) ^e	50	300	C,S,H,F,I,D
Glaucous-winged gull (<i>Larus glaucescens</i>)	150,000	300,000	C,S,H,F,I,D
Glaucous gull (<i>Larus hyperboreus</i>) ^e	30,000	2,000	C,S,H,I,D
Black-legged kittiwake (<i>Rissa tridactyla</i>)	800,000	1,000,000	C,S,P,F,M,Z
Red-legged kittiwake (<i>Rissa brevirostris</i>)	150,000	0	M,C,S,Z,P,F
Sabine's gull (<i>Xema sabin</i>)	Common	Common	?
Arctic tern (<i>Sterna paradisaea</i>) ^e	7,000	20,000	C,S,Z,F
Aleutian tern (<i>Sterna aleutica</i>)	9,000	25,000	C,S,Z,F
Common murre (<i>Uria aalge</i>)	3,000,000	2,000,000	C,S,H,O,F,Z
Thick-billed murre (<i>Uria lomvia</i>)	5,000,000	200,000	C,S,P,Q,Z,M,F,I
Pigeon guillemot (<i>Cephus columba</i>)	100,000	100,000	S,C,F,H,I
Marbled murrelet (<i>Brachyramphus marmoratus</i>)	Uncommon	Common	C,S,P,F,Z,I
Kittlitz's murrelet (<i>Brachyramphus brevirostris</i>)	Uncommon	Uncommon	S,C,H,Z,I,P,F
Ancient murrelet (<i>Synthliboramphus antiquus</i>)	200,000	600,000	Z,F,C,S,P,I
Cassin's auklet (<i>Ptychoramphus aleuticus</i>)	250,000	750,000	Z,Q,I,S,F
Least auklet (<i>Aethia pusilla</i>)	9,000,000	50	Z
Parakeet auklet (<i>Cyclorhynchus psittacula</i>)	800,000	150,000	F,I,S,P,Z
Whiskered auklet (<i>Aethia pygmaea</i>)	30,000	0	Z
Crested auklet (<i>Aethia cristatella</i>)	3,000,000	50,000	Z,I
Rhinoceros auklet (<i>Cerorhinca monocerata</i>)	50	200,000	C,S,H,A,F
Tufted puffin (<i>Fratercula cirrhata</i>)	2,500,000	1,500,000	C,S,P,F,Q,Z,I
Horned puffin (<i>Fratercula corniculata</i>)	500,000	1,500,000	C,S,P,F,Q,Z,I
Total	36,000,000	12,000,000	

Notes: ^aPopulation data for colonial seabirds that breed in coastal colonies were modified from USFWS 1998a. Estimates are minima, especially for storm-petrels, auklets, and puffins.

^bNumerical estimates are not available for species that do not breed in coastal colonies. Approximate numbers are as follows: abundant = 10 million or more; common = one to ten million, uncommon = 10,000 to 1 million, rare = 10,000 or less.

^cAbbreviations of diet components: M, Myctophid; P, walleye pollock; C, capelin; S, sand lance; H, herring; A, Pacific saury; F, other fish; Q, squid; Z, zooplankton; I, other invertebrates; D, detritus; ?, no information for Alaska. Diet components are listed in approximate order of importance, however, diets depend on availability and usually are dominated by one or a few items (see text).

^dFor sources of diet data, see species accounts in text.

^eSpecies breeds both coastally and inland; population estimate is only for coastal colonies.

Table 3.3-7 Comparative Population Estimates and Diets of Nonbreeding Seabirds That Frequent the Bering Sea and Aleutian Islands and Gulf of Alaska Regions

Species	Population ^{a, b}		Diet ^{c, d}
	BSAI	GOA	
Short-tailed albatross (<i>Diomedea abatrus</i>)	Rare	Rare	Q,F
Black-footed albatross (<i>Diomedea nigripes</i>)	Common	Common	Q,M,F,I,D
Laysan albatross (<i>Diomedea immutabilis</i>)	Common	Common	M,Q,I,F
Sooty shearwater (<i>Puffinus griseus</i>)	Common	Abundant	M,A,Q,C,S,F,Z
Short-tailed shearwater (<i>Puffinus tenuirostris</i>)	Abundant	Common	Z,F,C,S,I
Ivory gull (<i>Pagophila eburnea</i>)	Uncommon	0	?
Black guillemot (<i>Cepphus grylle</i>)	Rare	0	?

Notes: ^aPopulation data for colonial seabirds that breed in coastal colonies were modified from USFWS 1998a. Estimates are minima, especially for storm-petrels, auklets, and puffins.

^bNumerical estimates are not available for species that do not breed in coastal colonies. Approximate numbers are as follows: abundant = 10 million or more; common = one to ten million, uncommon = 10,000 to 1 million, rare = 10,000 or less.

^cAbbreviations of diet components: M, Myctophid; P, walleye pollock; C, capelin; S, sand lance; H, herring; A, Pacific saury; F, other fish; Q, squid; Z, zooplankton; I, other invertebrates; D, detritus; ?, no information for Alaska. Diet components are listed in approximate order of importance, however, diets depend on availability and usually are dominated by one or a few items (see text).

^dFor sources of diet data, see species accounts in text.

adults lack sufficient energy reserves to complete a nest, lay eggs, or complete incubation, or when they cannot feed the nestlings adequately.

Seabirds depend on forage fish that are small, high in energy content, and form schools within efficient foraging range of the breeding colony. Fish 5 to 20 cm long are easily captured and handled by seabirds. Schools must be available near the breeding colony, within 20 km or less for inshore feeders such as terns, guillemots, and cormorants, but up to 60 km or farther for kittiwakes and murre (Schneider and Hunt 1984). Some seabirds, such as kittiwakes and terns, can take prey only when they are concentrated at the surface; these species are affected more frequently by food shortages than are diving seabirds, such as murre, murrelets, puffins, and cormorants (Furness and Ainley 1984, Uttley et al. 1994).

Although Alaskan seabirds consume several fish species, only one or two forage species are available near most colonies. If an important fish stock is depleted locally, birds may have no alternative food source to support successful breeding. Regional variations in dominant forage fish include sand lance along most of the Aleutian Islands and the coast and northern islands of the Bering Sea (Springer 1991a, Springer et al. 1996); capelin and pollock on most of the Alaska Peninsula (Hatch and Sanger 1992, Springer 1991a); and pollock on Saint Matthew Island and the Pribilof Islands (Hunt et al. 1981, Hunt et al. 1981a, Springer et al. 1986).

The preferred forage species in each area usually is essential for successful seabird reproduction. Black-legged kittiwakes breed successfully in the northern Bering Sea when sand lance are available, but not in years when they have to rely on cods (Springer et al. 1987). After capelin declined in the GOA in the late 1970s, black-legged kittiwakes switched to pollock and sand lance, but this diet did not prevent breeding failure (Baird 1990, Piatt and Anderson 1996). Capelin have increased again near some GOA colonies since 1994, and kittiwake breeding success has improved in those areas (D.B. Irons, USFWS, Anchorage – personal communication).

Theories have attributed reductions in the forage fish of seabirds to both commercial fisheries and climatic cycles, however a National Research Council study (1996) concluded that both factors probably are significant. Climate has been recognized as the dominant factor in fluctuations of pelagic fish stocks (Wooster 1993), and climate in the GOA and Bering Sea undergoes cycles of varying lengths (Royer 1993), which influences the numbers and distribution of forage fish and hence avian productivity (National Research Council 1996, Piatt and Anderson 1996). This is also true for eastern Canada and northern Britain (Bailey 1989b, Carscadden 1984). However, directed fisheries on forage fish can deepen and prolong their natural low population cycles (Duffy 1983, Steele 1991). In nations with directed forage fish fisheries, some stocks have been decimated due to a combination of climatic and fishery pressures, which led to local population declines in seabirds. Examples include fisheries on anchoveta (*Engraulis ringens*) in Peru (Duffy 1983, Schaefer 1970), herring in Norway (Anker-Nilssen and Barrett 1991, Lid 1981), and pilchard (*Sardinops ocellata*) in South Africa (Crawford and Shelton 1978). In northwest Russia, where several forage species (capelin, herring, and Arctic cod) were overfished, sand lance are still available to seabirds, but the birds appear to compete for them more intensely than before (Krasnov et al. 1995).

Significance of Forage Fish to Marine Mammals

In general, small forage fish such as capelin, herring, sand lance, and eulachon have been recognized as important prey items for a variety of marine mammal species. Among these are northern fur seals, Steller sea lions, harbor seals, spotted seals, and bearded seals, as well as humpback whales and fin whales. Northern fur seals, Steller sea lions, and harbor seals have been declining in abundance for a number of years (Table 3.3-8), and some theories attribute these declines in part, to the lack of availability of prey species (Sinclair 1988, Sinclair et al. 1996, Merrick et al. 1997).

Largely due to the variable nature of the food habits data on different predators with respect to sampling method, timing, and location and lack of survey data on noncommercial prey species, the relative importance of forage species can appear uncertain. However, taken in aggregate, the available data suggest that forage fish species are important to marine mammals when and where they are available. Table 3.3-9 shows the relative rank of forage fish species in the diets of northern fur seals, Steller sea lions, and harbor seals in the GOA. Capelin are an important component of the diet of all three species. In addition, of those species forming the forage fish category, bathylagids and sand lance contribute to the diet of fur seals, with eulachon as another important component of harbor seal diets (Table 3.3-9). A summary of capelin and other forage fish use by selected marine mammal species in Alaska follows (data for pinnipeds is from the AFSC).

Northern Fur Seals

Examination of 1,800 stomachs collected from seals taken from the Bering Sea from 1960, 1962 to 1964, 1968, 1973, and 1974 indicated that capelin was the third-most prevalent prey item after pollock and Pacific herring (Kajimura 1985). Available information on fur seal feeding habits prior (1892 to 1950s) to these pelagic collections also describe capelin and bathylagid smelt as primary prey in seal spewings and stomachs. Pacific herring and capelin were absent from stomach samples collected in the 1980s. Absence of forage fish

Table 3.3-8 Numbers of Northern Fur Seals, Steller Sea Lions, and Harbor Seals in Parts of the Gulf of Alaska and Bering Sea

Year	Northern Fur Seal	Steller Sea Lion ^a	Harbor Seal ^b
1950	451,000		
1955	461,000		
1960	320,000	140,115	
1965	253,768		
1970	230,485		
1975	278,261	103,976	
1976	298,000		6,919
1977	235,200		6,617
1978	247,100		4,839
1979	245,932		3,836
1980	203,825		
1981	179,444		
1982	203,581		1,575
1983	165,941		
1984	173,274		1,390
1985	182,258	67,617	
1986	167,656		1,270
1987	171,422		
1988	202,300		1,014
1989	171,530	24,953	
1990	201,310	27,860	960

Notes: ^aIndex counts of adults and juveniles on rookeries and haulouts from the Kenai Peninsula to Kiska Island are from Loughlin et al. (1990) and Merrick et al. (1991, 1987).

^bMean counts of seals hauled out on Tugidak Island during the fall molt are from Pitcher (1990) and ADF&G (unpublished data).

in the samples was thought to be related to fluctuations in the abundance and availability of these fish, environmental changes in the Bering Sea, or exclusion by the existence of large populations of pollock.

Steller Sea Lions

Stomach samples collected by ADF&G in the eastern Bering Sea in 1981 and 1985 to 1986 did not indicate the presence of forage fish species, but rather contained predominantly pollock and yellowfin sole (Calkins 1998, Gearin - unpublished report). However, 37 samples collected in the GOA during summer from 1975 to 1978 showed that capelin comprised about 60 percent of the stomach contents identified (Pitcher 1981).

Harbor Seals

Analyses of harbor seal stomach contents from collections made by ADF&G during 1973 to 1978 in the GOA indicated the presence of several forage fish species, including capelin, eulachon, Pacific herring, and Pacific sand lance. In particular, capelin, eulachon, and Pacific herring ranked third, fourth, and fifth respectively out of 15 species compared using the index of relative importance method. Seasonal and area differences were pronounced; capelin were most common in collections from the Kodiak Island area, but were absent in samples

Table 3.3-9 Rank of Prey Species in the Diets of Northern Fur Seals, Steller Sea Lions, and Harbor Seals in the Gulf of Alaska and Bering Sea

Ranking	Northern Fur Seal ^a	Steller Sea Lion ^b	Harbor Seal ^c
1	Squids (33.3)	Pollock (58.3)	Pollock (21.4)
2	Capelin (30.6)	Herring (20.6)	Octopus (18.3)
3	Pollock (25.1)	Capelin (7.4)	Eulachon (11.6)
4	Atka mackerel (3.5)	Salmon (5.1)	Capelin (10.4)
5	Herring (2.9)	Squid (4.2)	Herring (6.4)
6	Bathylagidae (2.9)	Sculpins (1.3)	Salmon (4.4)
7	Salmon (1.1)	Pacific cod (0.9)	Shrimps (3.3)
8	Flatfishes (0.6)	Rockfishes (0.8)	Pacific cod (3.2)
9	Sablefish (0.2)	Flatfishes (0.3)	Flatfishes (2.6)
10	Sand lance (0.2)	Octopus (<0.1)	Squids (1.6)

Notes: ^aRankings based on modified volume, numbers in parentheses are modified volumes; from Perez and Bigg (1981).

^bRankings based on combination rank index, numbers in parentheses are percent of total sample volume; from Pitcher and Calkins (1981).

^cRankings based on modified index of relative importance, numbers in parentheses are percent of total sample volume; from Pitcher (1980a, 1980b).

from the south side of the Alaska Peninsula. Similarly, eulachon comprised 95 percent of the contents volume for collections in the Copper River Delta, 30 percent in lower Cook Inlet, and 4.6 percent around Kodiak Island (Pitcher 1980).

Spotted Seals

Collections of 14 spotted seal stomachs during March–June 1976 to 1978 in the southeastern Bering Sea indicated that capelin was the predominant prey item. Similar collections from spotted seals in the northern Bering Sea in 1976 to 1978 contained predominantly Arctic cod, capelin, and saffron cod. In March–June 1972 and 1973, spotted seal collections from the Gulf of Anadyr contained predominantly Arctic cod, but pollock and sand lance were present as well (Bukhtiyarov et al. 1984).

Bearded Seals

Pelagic collections of bearded seal stomachs near Saint Matthew Island in the Bering Sea in spring 1981 indicated a very high occurrence of capelin in the diet, 82 percent, based on 16,940 individual capelin remains recovered (Antonelis et al. 1994). The authors suggest that the high occurrence was related to the presence of dense schools of capelin that rise in the water column and move toward shore in early spring. This prey species, like other forage fish, therefore, may be very important in specific areas and times of year, but would not necessarily appear as important prey if sampling were to occur at different places and times.

Humpback Whales

The major prey species of humpback whales are small schooling fishes, including juvenile pollock, and large zooplankton, mainly euphausiids. Important prey species in southeastern Alaska are capelin, herring, pollock,

and krill. Shifts in distribution of humpback whales in southeastern Alaska have also been documented in apparent response to changes in prey abundance (Nemoto 1957).

Fin Whale

Fin whales are seasonally associated with coastal and continental shelf habitats and food resources. In the North Pacific Ocean, fin whales compete with commercial fisheries for common prey species such as herring, northern anchovy, pollock, capelin, sand lance, and lantern fish (Kajimura and Loughlin 1988). Data compiled over the past 25 years (AFSC unpublished data) suggest that these whales feed in eastern North Pacific waters (e.g., Shelikof Strait and the GOA).

Commercial Forage Fish Harvest

Forage fish form only a small part of the bycatch of commercial groundfish fisheries. Forage fish are taken incidental to the Alaska groundfish trawl fisheries in amounts of less than 1 percent of any directed fishery (L. Fritz, NMFS Alaska Fisheries Science Center – personal communication). Annual osmerid bycatch (principally capelin caught by the yellowfin sole fishery) by all groundfish fisheries in the BSAI ranged between 43–800 mt in 1992 to 1995 (Fritz 1996). Annual bycatch totals by BSAI groundfish fisheries of a wide variety of other fish (including bathylagids, myctophids, sandfish, sand lance, eelpouts, snipe eels, greenlings, lumpfishes, pricklybacks, and snailfishes) have amounted to about 1,000 mt for both 1994 and 1995 (Fritz 1996). Table 3.3-10 shows the forage fish complex catch estimate for the groundfish fisheries in the BSAI (63 mt) and GOA (239 mt) for 1999. While it is not known what percentage these values are of their actual biomasses in the BSAI, this bycatch amount probably has little effect on the reproducibility of each species, nor does it represent significant competition with other apex predators (marine mammals, birds, and other fish).

Because a specific reporting category exists for smelt, some catch data are available for this species group. Data from the GOA for 1990 to 1993 indicate that smelt is taken as bycatch, predominately in the bottom pollock, pelagic pollock, and rockfish trawl fisheries, with total annual bycatch amounts ranging from 127.2 to 530.7 mt. In the BSAI, smelt bycatch occurs mainly in the yellowfin sole fishery and, to a lesser extent, in the pelagic pollock fishery. Total annual smelt bycatch by all groundfish fisheries in the BSAI area ranged from 31.8 to 292.1 mt during 1990 to 1993. These data indicate that both midwater and bottom trawl fisheries capture incidental amounts of forage fish.

Although little commercial fishing occurs on forage fish species, documentation exists of a small and sporadic commercial fishery on capelin as early as the 1960s (ADF&G 1993b). The largest harvest of capelin was taken in 1984 (489 mt, sorted), and in 1993, 31 mt of capelin were harvested in Nunavachuk Bay. Data reveal that no more than three vessels per year participated in a capelin fishery. Data from 1992 and 1994 indicate that less than 1 mt of capelin was commercially harvested by one boat. The limited annual harvest of capelin in the North Pacific Ocean is due to sporadic market conditions, processing limitations, and fluctuation of available capelin biomass. However, declining Atlantic stocks have the potential to change the market interest for capelin.

Presently, commercial fishing for capelin is open by regulation, not managed by emergency order, and is restricted by few regulations. The opportunity for a directed fishery on capelin or the other forage fish species exists under the current management system. Presently, species contained in the proposed forage fish category are not actively managed by the State of Alaska; however, cooperative state and federal management would be necessary for those forage fish that may be distributed in state waters during spawning times.

Table 3.3-10 Estimated Catch of Forage Fish by Target Fishery and Gear Type by Groundfish Fisheries in the Bering Sea and Aleutian Islands and the Gulf of Alaska, 1999, in Metric Tons

Target	Gear	Target Catch (t)	Osmerids	Sandfish	Others ^a
A. Bering Sea and Aleutian Islands					
Atka mackerel	Trawl	43,025	0	0	0
Pollock	Bottom trawl	64,527	38	0	0
Pollock	Pelagic trawl	730,413	39	0	0
Pacific cod	Trawl	26,925	1	1	0
Pacific cod	Pot	4,268	0	0	0
Pacific cod	Longline	6,436	0	0	0
Flatfish	Trawl	1,712	20	0	0
Rockfish	Trawl	12,101	0	0	0
Rockfish	Longline	7	0	0	0
Rock sole	Trawl	0	0	0	0
Sablefish	All	0	0	0	0
Turbot	Trawl	591	0	0	0
Turbot	Longline	2,371	0	0	0
Yellowfin sole	Trawl	33,217	2	0	0
All species	Trawl	922,618	61	2	0
All species	Pot	4,282	0	0	0
All species	Longline	63,171	0	0	0
B. Gulf of Alaska					
Pollock	Bottom trawl	2,530	2	0	0
Pollock	Pelagic trawl	26,235	23	0	0
Pacific cod	Trawl	4,868	15	0	0
Pacific cod	Pot	1,575	45	0	0
Pacific cod	Longline	1,406	1	0	0
Flatfish	Trawl	13,556	9	0	0
Flatfish	Longline	1	0	0	0
Rockfish	Trawl	9,957	101	0	0
Rockfish	Longline	10	0	0	0
Sablefish	Trawl	84	0	0	0
Sablefish	Longline	1,843	2	0	0
All species	Trawl	48,365	150	0	0
All species	Pot	1,575	45	0	0
All species	Longline	7,866	22	0	0

Notes: ^aOthers are composed of the following species groups: bathylagids, gunnels, and pricklebaks.

Subsistence Harvest of Forage Fish

The ADF&G Subsistence Division conducts household surveys to determine subsistence use of forage fish species. Data from these surveys show that smelt are reported harvested in a large number of coastal communities in the southeast, southcentral, southwest, west, and arctic regions of Alaska. Reported smelt

harvests range from a few pounds to several thousand pounds per community, depending on place and year. In the southeast, southcentral, and southwest regions, eulachon are the smelt most commonly taken. Rainbow smelt, capelin and unknown smelt are also reported harvested in communities in the arctic, west, southwest, and southcentral regions. The ADF&G database contains no records of subsistence harvests of other forage fish categories; however, it is possible that, in particular communities, some subsistence harvests of other forage fish species may occur (B. Wolfe, Alaska Department of Fish and Game, Subsistence Division – personal communication).

3.3.2 Ecological Relationships Between Target Species and Other Species

This section summarizes information on the ecological relationships between target species and other species of the groundfish communities in the eastern Bering Sea, GOA, and the Aleutian Islands areas using data from the AFSC food habits database, the primary data source for most target species and published reports for other species. The trophic relationships between the species that form the food webs in the groundfish communities are described. In each ecosystem, the target species were categorized into six groups: benthic invertebrate feeders, benthic mixed fish and invertebrate feeders, benthic piscivores, pelagic zooplanktivores, pelagic mixed zooplankton and fish feeders, and pelagic piscivores. It should be noted that these categories are somewhat artificial since individual fish species may exhibit size-related, seasonal, geographic, or interannual diet changes, which may change them from one category to another. The categories are considered illustrative of the general feeding strategy for adults of each species.

Eastern Bering Sea

The generalized eastern Bering Sea food web (Figure 3.3-10) is based upon diet data from the eastern Bering Sea shelf (less than 200 m) during the primary feeding season for the predators (May–September).

Benthic Invertebrate Feeders

In the eastern Bering Sea, groundfish species fit into each of the benthic groups. Yellowfin sole, Alaska plaice, and rock sole are primarily invertebrate feeders. The largest dietary components of these species are benthic invertebrates such as polychaete and other marine worms, bivalves, and gammarid amphipods. Pacific sand lance appear as a substantial component of the rock sole diet, however, this predation primarily occurs in large rock sole at limited areas and time (Lang et al. 1995). Therefore, rock sole are not grouped as a piscivorous species in this analysis.

Other eastern Bering Sea flatfish species that fall into this category include rex sole and starry flounder. Amphipods, clams, and polychaetes account for 90 percent of the diet of rex sole in the eastern Bering Sea (Brodeur and Livingston 1988). The diet of starry flounder is primarily (95 percent by weight) clams (Brodeur and Livingston 1988).

Three eelpout species also fall into this category, although their diets are quite dissimilar. Twoline eelpouts primarily consume amphipods and other benthic crustaceans (Brodeur and Livingston 1988). Shortfin eelpouts consume up to 90 percent of their diet in the form of brittle stars (Brodeur and Livingston 1988). Wattled eelpouts consume a mixture of Tanner crab and snow crab, gammarid amphipods, and polychaete worms (Brodeur and Livingston 1988).

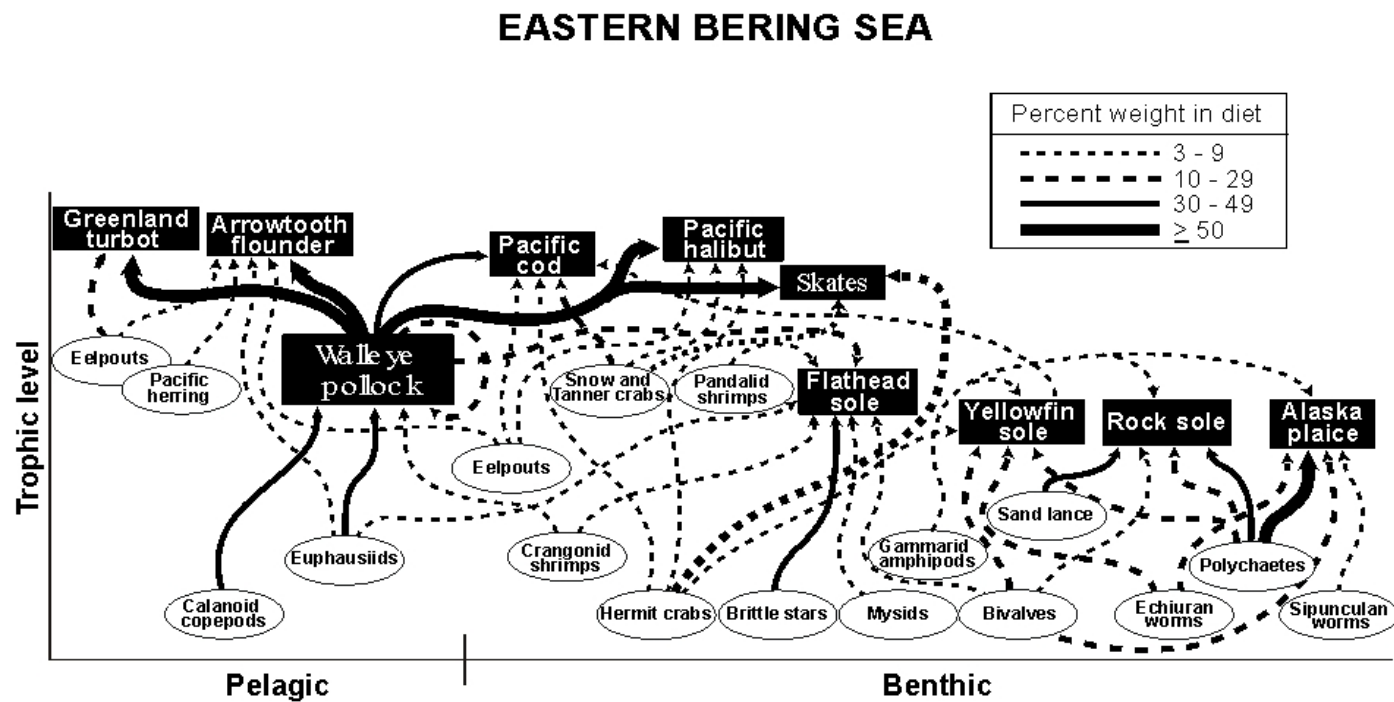


Figure 3.3-10 Trophic interactions of key eastern Bering Sea groundfish. Source: NMFS

Red Irish lords, sturgeon poachers, and gunnells (Pholidae) are also characterized as benthic invertebrate feeders. The primary prey (75 percent by weight) of red Irish lords in the eastern Bering Sea are hermit crabs, followed by Tanner crab and snow crab (Brodeur and Livingston 1988). Sturgeon poachers consume benthic amphipods (80 percent of the diet by weight) and decapod crustaceans (Brodeur and Livingston 1988). Gunnells consume a wide range of benthic invertebrates (NPFMC 1997).

Benthic Mixed Fish and Invertebrate Feeders

Pacific cod, Pacific halibut, skate, and flathead sole are all characterized as having a mixed fish and invertebrate diet (Figure 3.3-10). Flathead sole receives this characterization due to the presence of pollock, brittle stars, crangon shrimp, mysids, and bivalves in their diet. Fish are a relatively small portion of small (less than 20 cm) flathead sole diets, but are increasingly important with size (Livingston and deReynier 1996) and warrant their placement in this category. Although Pacific cod are not as obviously benthic as many of the flatfishes, they are considered a benthic predator. Pacific cod consume a wide variety of benthic invertebrate prey, as well as walleye pollock and pleuronectids such as yellowfin sole. While Pacific cod of all sizes prey heavily on benthic invertebrates, especially bairdi Tanner crab and opilio Tanner crab (also called snow crab), fish prey become increasingly important with size (Livingston and deReynier 1996). Pacific halibut and skate are benthic species that consume invertebrates more at smaller sizes but have a large fish component to their diet (Figure 3.3-10). This fish component is dominant at the larger sizes of these fish. Pollock are the primary prey of these species, although Pacific halibut consume other fish prey as well (i.e., eelpouts). Hermit crab, bairdi Tanner crab, and opilio Tanner crab are also important prey of these two species.

Two large sculpins are also characterized as having a mixed fish and invertebrate diet. Plain sculpins in the eastern Bering Sea consume fish (pleuronectids) and crab species (Tanner and hermit) almost exclusively (Brodeur and Livingston 1988). Great sculpins rely upon pollock (20 percent by weight) and Tanner crab and snow crab (50 percent by weight) as their main dietary components (Brodeur and Livingston 1988).

Grenadiers that inhabit the upper continental slope generally prey on locally abundant fish and invertebrates and scavenge for carcasses (Okamura 1970, Percy and Ambler 1974, Drazen et al. In press). The popeye grenadier is the most numerically abundant grenadier in this region (Bohle 1988), and it likely has this type of feeding strategy. The giant grenadier feeds on myctophids, squid, and a variety of benthic and mesopelagic animals in the eastern Bering Sea (Novikov 1970): eelpouts, other fish, and shrimp were identified as its dominant prey from samples taken in the 1980s (Brodeur and Livingston 1988).

Non-target species like the large, demersal Pacific sleeper shark can be categorized in this group. Yang and Page (1999) reported that arrowtooth flounder was the most important prey of sleeper shark in the GOA, representing 67 percent of the total stomach content weight. Other prey in the GOA included pollock, rockfish, Pacific salmon, flathead sole, and octopus (*Octopus dofleini*). Other studies have reported flatfish, salmon, rockfish, octopus and squid, crab, seal, and carrion (Hart 1973) as prey items. Sleeper sharks in the eastern Bering Sea are likely to consume similar prey.

Benthic Piscivores

Pacific sandfish and bigmouth sculpin fall into this category, as over 90 percent of their diets are composed of fish, especially gadids (Brodeur and Livingston 1988).

Pelagic Mixed Fish and Zooplankton Feeders

Pollock appear to be primarily zooplanktivores, consuming calanoid copepods and euphausiids as their primary prey (Figure 3.3-10). However, pollock also exhibit some piscivory, primarily in the form of cannibalism, placing them in the group of mixed fish and zooplankton consumers. Pollock also have a small benthic component to their diet.

Northern rockfish consume fish and euphausiids as the two most important prey by weight (Brodeur and Livingston 1988), placing them in the group of pelagic predators with a diet of mixed fish and zooplankton. Atka mackerel are also members of this group due to the reliance on pollock and euphausiids as the two most important prey in their diet (Brodeur and Livingston 1988). In the GOA, these two species are categorized as primarily zooplanktivorous.

Pelagic Piscivores

Arrowtooth flounder and Greenland turbot are primarily piscivorous in the eastern Bering Sea (Figure 3.3-10). Arrowtooth flounder primarily consume walleye pollock and eelpouts on the eastern Bering Sea shelf. However, euphausiids are a large portion of the diet of smaller (less than 20 cm) arrowtooth flounder (Livingston and deReynier 1996). In the deeper slope waters, squid become an important part of the diet of arrowtooth flounder (Lang and Livingston 1996). Greenland turbot are almost exclusively piscivorous on the eastern Bering Sea shelf. The dominant prey of Greenland turbot is pollock, however, eelpouts also contribute to their diet. Very small (less than 20 cm) Greenland turbot have a large euphausiid component to their diet (Livingston and deReynier 1996). In the deeper slope region, Greenland turbot consume squid as well as pollock (Lang and Livingston 1996). Sablefish are primarily piscivorous on species such as pollock (Brodeur and Livingston 1988). However cephalopods are their most important prey after fish. Salmon shark are opportunistic pelagic predators of many species of fish and squid as well as benthic invertebrates.

Pelagic Zooplankton Feeders

Pacific herring are an example of pelagic zooplanktivores; copepods and euphausiids make up 95 percent of their diet by weight (Brodeur and Livingston 1988). The most important prey in the diet of Pacific ocean perch from the eastern Bering Sea are euphausiids, which make up 45 percent of the diet (Brodeur and Livingston 1988), placing them in this group of zooplankton feeders. Unspecified caridean shrimp are their second-most important prey. Many forage fish species also fit into this category. Capelin, eulachon, myctophids, bathylagids, and stichaeids are all pelagic predators of zooplankton (NPFMC 1997). Euphausiids and copepods are the primary prey of these species, although many other pelagic prey (i.e., pteropods, ctenophores, jellyfish, chaetognaths) are also found in their diets.

Gulf of Alaska

Benthic Invertebrate Feeders

Smaller flatfish, such as flathead sole, rock sole, and yellow fin sole, are included in the benthic invertebrate feeders category. They mainly feed on benthic and epibenthic invertebrates such as shrimps, crab, polychaetes, bivalves, hermit crab, and gammarid amphipods.

Yang and Nelson (2000) found that pandalid shrimp was the most important prey of flathead sole in the GOA in 1993. It comprised 32 percent of the total stomach content's weight. Brittle stars were the second-most

important food of flathead sole in GOA. Flathead sole also fed on other benthic or epibenthic invertebrates, such as hermit crabs, crangonid shrimp, Tanner crab, and gammarid amphipods (Figure 3.3-11).

Rogers et al. (1987) showed that rock sole and yellowfin sole had generalized diets. They fed mainly on polychaetes. However, rock sole took mainly motile forms of polychaetes (errantiaes), whereas the yellowfin sole consumed more nonmotile forms (sedentariates). Most of the crab they consumed (e.g., *Telmessus cheiragonus*, *Pugettia gracilis*, and *Cancer oregonensis*) were not commercially important. They also consumed clams and gammarid amphipods (Figure 3.3-11).

Non-target species such as starry flounder, rock greenling, kelp greenling, masked greenling, and white spotted greenling can also be categorized in this group of benthic primary invertebrate feeders. Rogers et al. (1987) and Rosenthal (1983) found that these greenlings fed mainly on gammarids, crab (most non-commercially important), shrimp, caprellids, mysids, and small amounts of fish. Rosenthal (1983) reported that starry flounder fed on clam siphons, cancrid crab, brittle stars, and polychaetes.

Benthic Mixed Fish and Invertebrate Feeders

Pacific cod, Pacific halibut, rougheye rockfish, shortraker rockfish, and shortspine thornyhead are categorized in this group. They feed mainly on the bottom but also in the water column. Because of the high diversities in their diets, they are subdivided into two groups: (1) the Pacific cod and Pacific halibut group; and (2) the rougheye rockfish, shortraker rockfish, and shortspine thornyhead group. The diets of Pacific cod and Pacific halibut include high proportions of fish and crab, whereas the diets of rougheye rockfish, shortraker rockfish, and shortspine thornyhead consist of large amounts (44 percent or more by weight) of shrimp (pandalids and crangonids). Yang and Nelson (2000) showed that Pacific cod and Pacific halibut had high diet overlap value of 64 percent by weight of the total stomach contents. Diet overlaps between the three rockfishes in this group were more than 50 percent.

Yang and Nelson's (2000) study showed that the prey fish in the Pacific cod diet in 1996 consisted of 23 percent (by weight) pollock, 4 percent Atka mackerel, and small amounts (1 percent or less) of zoarcids, cottids, searchers, stichaeids, capelin, rock sole, and arrowtooth flounder. The invertebrates that Pacific cod consumed included 11 percent Tanner crab, 11 percent hermit crab, 6 percent lyre crab, 11 percent pandalid shrimp, 5 percent crangonid shrimp, and 6 percent polychaetes (Figure 3.3-11).

Compared to Pacific cod, Pacific halibut consumed more fish and crab but a much lesser amount of shrimp. Because Pacific halibut grow to such a large size, they also feed on more varieties of fish, such as rock sole, yellowfin sole, Dover sole, and Pacific cod. Yang and Nelson (2000) reported that pollock was the most important prey of Pacific halibut (32 percent by weight) in the GOA in 1996. Other prey fish included 6 percent Atka mackerel, 4 percent capelin, and small amounts (3 percent or less) of Pacific sand lance, rock sole, yellowfin sole, zoarcids, cottids, searchers, stichaeids, arrowtooth flounder, Dover sole (*Microstomus pacificus*), and Pacific cod. The important invertebrates consumed by Pacific halibut included Tanner crab (9 percent), hermit crab (15 percent), lyre crab (6 percent), and small amounts (3 percent or less) of decorator crab, cancrid crab, and octopus (Figure 3.3-11).

Yang and Nelson (2000) found that the diet of rougheye rockfish in 1993 was 50 percent (by weight) pandalid shrimp, 10 percent crangonid shrimp, 11 percent euphausiids, and 5 percent eulachon. Other prey fish included walleye pollock, Pacific herring, Pacific sand lance, myctophids, zoarcids, cottids, snailfish, and flatfish. Commercially important Tanner crabs were also consumed by rougheye rockfish, comprising 1 percent of the total stomach content weight in 1993.

GULF OF ALASKA

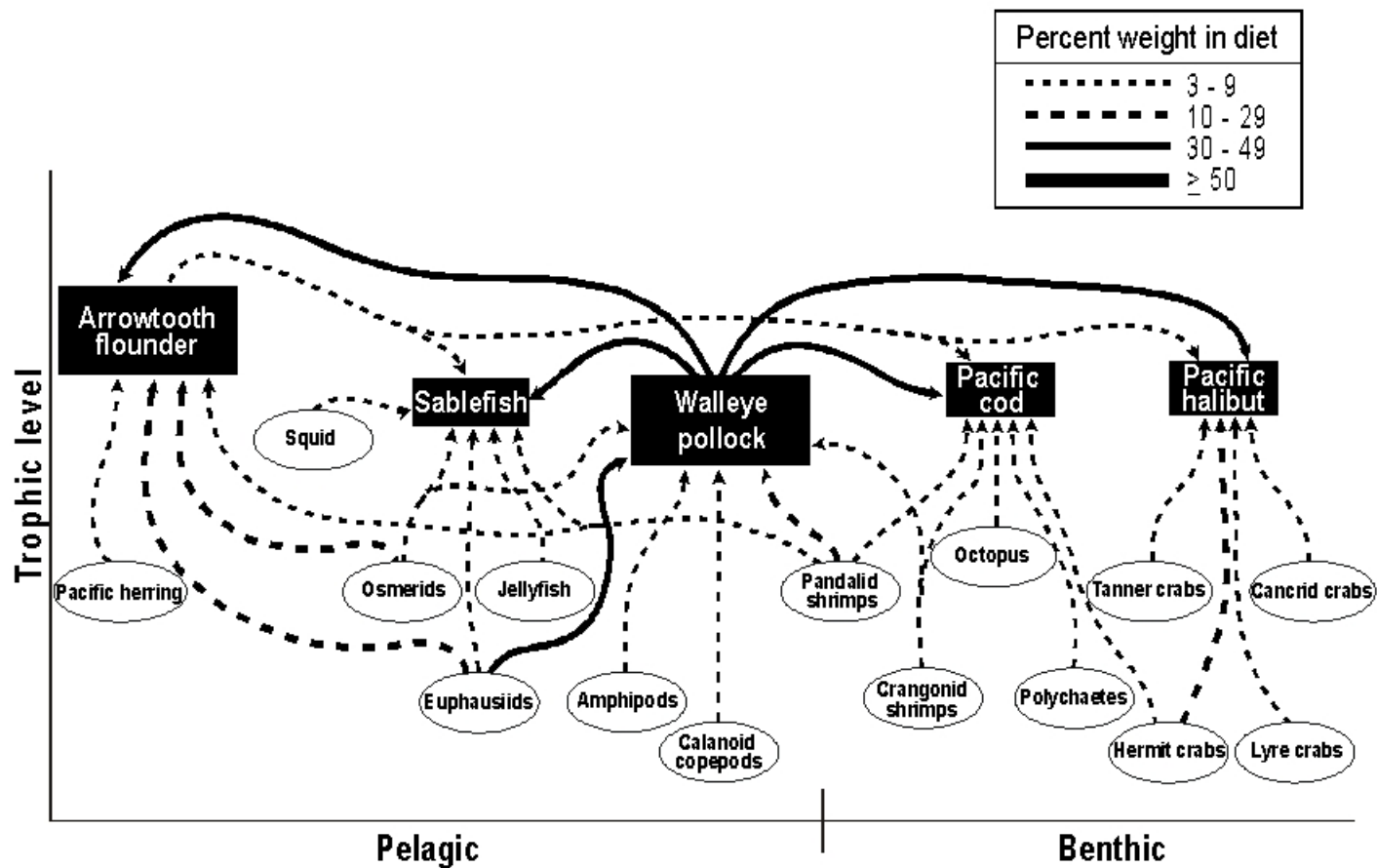


Figure 3.3-11 Trophic relationships of the groundfishes in the Gulf of Alaska. Source: NMFS.

Shrimp (mainly pandalids) were the most important food of thornyheads (61 percent by weight) in 1993 (Nelson and Young 2000). Tanner crab comprised 7 percent of the food of thornyheads; fish (pollock, zoarcids, and sculpins) comprised 12 percent. Other prey items included polychaetes, mysids, amphipods, and other crabs (mainly decorator crab).

Compared to rougheye rockfish and shortspine thornyhead, shortraker rockfish eat fewer prey items. Yang and Nelson's (2000) study showed that pandalid shrimp, comprising 50 percent of total stomach content weight, was the most important food of shortraker rockfish in 1993, and that squid was the second-most important, comprising 35 percent of total stomach content weight.

Non-target species like great sculpins and red Irish lords can also be categorized in this group of mixed fish and invertebrate feeders. Rogers et al. (1987) found that fish and crab comprised about 50 percent of the total stomach content weight of great sculpins. Rosenthal (1983) reported that red Irish lords fed on kelp greenlings, brittle stars, octopus, hermit crabs, gastropods, and sipunculid worm.

The giant grenadier, popeye grenadier, and Pacific grenadier are common in the GOA. Studies of the feeding habits of giant and Pacific grenadiers in other areas indicate that they prey on and scavenge carcasses of locally abundant fish, squid, and other benthic and mesopelagic animals (Novikov 1970, Pearcy and Ambler 1974, Buckley et al. 1999, Drazen et al. In press) and it is likely that grenadier in the GOA have a similar diet.

Non-target species, such as Pacific sleeper shark, can be categorized in this group. Yang and Page (1999) reported that arrowtooth flounder was the most important prey of sleeper shark, representing 67 percent of total stomach content weight. Other prey included pollock, rockfish, Pacific salmon, flathead sole, and octopus.

Pelagic Piscivores

Arrowtooth flounder is categorized in the group of pelagic primary piscivores. They feed mainly on fish in the water column. Compared to Pacific cod and Pacific halibut (the mixed fish and invertebrate feeders), arrowtooth flounders had a high percentage (about 60 percent) of prey fish and almost no crab in their diet. However, arrowtooth flounders did consume more euphausiids than either Pacific cod or Pacific halibut. In general, arrowtooth flounders consumed more pandalid shrimp than Pacific halibut, and in the GOA in 1996 their diet was comprised of 53 percent (by weight) pollock, 10 percent capelin, and small percentages (no more than 2 percent) stichaeids, bathylagids, salmonids, zoarcids, cottids, searchers, eulachon, rock sole, and Pacific cod (Yang and Nelson 2000). Although arrowtooth flounders fed mainly on fish, the diet of smaller-sized fish also included euphausiids, pandalid shrimps, and crangonid shrimps (Figure 3.3-11).

Lingcod is also categorized in the group of pelagic primary piscivores. Rosenthal (1983) found that Pacific sand lance was the most important food of lingcod. Other prey fish included black rockfish, dusky rockfish, and kelp greenling.

Non-target species, such as salmon shark and spiny dogfish, can be categorized in this group. The diet of salmon shark includes salmonids, rockfish, lancetfish, daggertooth, sablefish, spiny dogfish, lumpfishes, myctophids, sculpin, pollock, Pacific herring, Pacific halibut, and squid. The main foods of spiny dogfish are Pacific herring, Pacific sand lance, smelts, and euphausiids (NPFMC 1999a).

Pelagic Zooplanktivores

Atka mackerel, Pacific ocean perch, northern rockfish, and dusky rockfish are categorized in the pelagic primary zooplanktivores group. They feed mainly in the upper water column. Zooplankton (including

euphausiids, calanoid copepods, larvaceans, chaetognaths, and hyperiid amphipods) and gelatinous invertebrates (jellyfish) comprised more than 80 percent of the stomach contents of each of these species (Yang and Nelson 2000). Pacific ocean perch and northern rockfish had high diet overlap since they all fed largely (equal to or more than 60 percent) on euphausiids. Compared to Pacific ocean perch and northern rockfish, Atka mackerel consumed a high percentage (64 percent) of calanoid copepods but a low percentage (4 percent) of euphausiids. However, in the Aleutian Islands, euphausiids dominated (55 percent) the diet of Atka mackerel (Yang 1996).

Yang and Nelson (2000) reported that the diet of Atka mackerel in the GOA consisted of 64 percent (by weight) calanoid copepods, 19 percent jellyfish, 12 percent gastropods, 4 percent euphausiids, and 1 percent hyperiid amphipods (Figure 3.3-11). The diet of Pacific ocean perch in 1990 comprised 60 percent euphausiids, 11 percent amphipods, 7 percent calanoid copepods, 5 percent pandalid shrimp, and 4 percent chaetognaths (Yang and Nelson 2000). The diet of northern rockfish in 1990 also contained a high percentage (88 percent) of euphausiids. Other prey items of northern rockfish included chaetognaths, calanoid copepods, and hyperiid amphipods. Yang and Nelson (2000) found that euphausiids were the most important food (61 percent by weight) of dusky rockfish. Larvaceans were the second-most important prey of dusky rockfish; they comprised 14 percent of total stomach content weight. Dusky rockfish also consumed 8 percent chaetognaths, 8 percent hermit crabs, and small amounts (less than 5 percent) of pandalids, hippolytids, gammarid amphipods, and calanoid copepods.

Forage species, such as bathylagids, myctophids, eulachon, Pacific sand lance, and capelin, can be categorized in this group. Bathylagids consume plankton (euphausiids, calanoid copepods, pteropods, appendicularia, chaetognath, and gelatinous animals such as ctenophores and jellyfish). Myctophids consumed mostly calanoid copepods and euphausiids. Eulachon mainly feed on euphausiids, calanoid copepods, and cumaceans. Pacific sand lance prey upon chaetognaths, amphipods, calanoid copepods, and fish larvae. Euphausiids and calanoid copepods are common to the diet of capelin, although marine worms and small fish are also part of their diet (NPFMC 1997).

Pelagic Mixed Zooplankton and Fish Feeders

Pollock and sablefish are categorized in this group, which feeds not only on zooplankton but also on fish and shrimp. Compared to the primary zooplanktivores (80 percent of their diets were zooplankton), the zooplankton and fish feeders consume less zooplankton (no more than 60 percent of their diets). On the other hand, the combination of the fish and shrimp consumed by the zooplankton and fish feeders can be as high as 40 percent (Yang and Nelson 2000).

Pollock plays an important trophic role in the GOA. They are important prey of many groundfish species: Pacific halibut, Pacific cod, arrowtooth flounder, and sablefish. Pollock also consume their young. Yang and Nelson (2000) reported that the diet of walleye pollock in the GOA in 1993 comprised 41 percent euphausiids, 20 percent pandalid shrimp, 6 percent larvaceans (pelagic tunicates), 4 percent calanoid copepods, and small amounts (no more than 3 percent) of capelin, Pacific sand lance, eulachon, zoarcids, cottids, stichaeids, squids, and amphipods (Figure 3.3-11).

Compared to pollock, sablefish consumed more fish (mainly juvenile pollock) but less euphausiids and shrimp. It is worth noting that sablefish was the only groundfish that consumed a high percentage (32 percent by weight in 1996) of fish offal (fish carcasses) in the GOA. Another special prey for sablefish was jellyfish. Yang and Nelson (2000) found that in 1996 sablefish fed mainly on euphausiids (10 percent of total stomach content weight), amphipods (11 percent), jellyfish (14 percent), pollock (10 percent), pandalid shrimp (5 percent), and small amounts (no more than 3 percent) of squids, polychaetes, and hermit crab (Figure 3.3-11).

Aleutian Islands

Benthic Invertebrate Feeders

Rock sole is included in this category. They mainly feed on benthic and epibenthic invertebrates, such as polychaetes, bivalves, hermit crab, gammarid amphipods, brittle stars, and gastropods. Simenstad et al. (1977) reported that polychaetes were the most frequently occurring (53 percent) prey of rock sole in the Amchitka Island area, followed by gammarid amphipods (29 percent), brittle stars (6 percent), bivalves (6 percent), gastropods (6 percent), and hermit crabs (6 percent) (Figure 3.3-12). In the eastern Bering Sea and GOA, yellowfin sole and flathead sole were included in the primary invertebrate feeders group. Trophic information for these two species in the Aleutian Islands is lacking, but is assumed to be similar to that of the eastern Bering Sea and GOA.

Non-target species, such as rock greenling and armorhead sculpin (*Gymnocanthus galeatus*), can be categorized in this group of benthic primary invertebrate feeders. Simenstad et al. (1977) reported that rock greenlings fed on gastropods, bivalve mollusks, amphipods, isopods, and polychaetes. Armorhead sculpin also rely on benthic amphipods, isopods, and polychaetes as food.

Benthic Mixed Fish and Invertebrate Feeders

Pacific cod, Pacific halibut, roughey rockfish, shortraker rockfish, and shortspine thornyhead are categorized in this group. They feed mainly on the bottom, but also in the water column. Because of the high diversities in their diets, they are subdivided into two groups: (1) the Pacific cod and Pacific halibut group; and (2) the roughey rockfish, shortraker rockfish, and shortspine thornyhead group. The diets of the Pacific cod and Pacific halibut include high proportions of fish and crabs whereas the diets of roughey rockfish, shortraker rockfish, and shortspine thornyhead consist of large amounts of shrimp (pandalids and crangonids). Yang (1996) showed that Pacific cod and Pacific halibut had a high diet overlap value of 62 percent by weight of total stomach content, and shortraker rockfish and shortspine thornyhead had high diet overlap value (56 percent).

Yang (1996) found that the prey fish of Pacific cod consisted of 27 percent (by weight) Atka mackerel, 17 percent pollock, 7 percent cottids, and small amounts (no more than 3 percent) myctophids, flatfish, rockfish, Pacific herring, snailfish, bathylagids, Pacific sand lance, stichaeids, searchers, and viperfish. Invertebrates consumed by Pacific cod included 9 percent squids, 6 percent pandalid shrimp, 4 percent octopus, and small amounts (no more than 3 percent) Tanner crab, Korean horsehair crab (*Erimacrus isenbeckii*), hermit crab, euphausiids, calanoid copepods, and polychaetes. (Figure 3.3-12).

The diet of Pacific halibut is very similar to that of Pacific cod, except that Pacific halibut consumed more cephalopods and fewer Atka mackerels than did Pacific cod (Yang 1996). Yang's (1996) study showed that the stomach contents of Pacific halibut consisted of 19 percent pollock, 12 percent Atka mackerel, 17 percent squid, 10 percent octopus, 7 percent Tanner crab, 5 percent capelin, and small amounts (no more than 3 percent) sablefish, flatfish, Pacific herring, sculpins, Pacific cod, rockfish, searchers, hermit crab, lyre crab, and gastropods.

Roughey rockfish, shortraker rockfish, and shortspine thornyhead are included in this category. These fish feed mainly on shrimp (pandalids and hippolytids), and on certain amounts of fish like myctophids, cottids, and snailfish. Yang (1996) found that shrimp, comprising 45 percent of total stomach content weight, was the primary invertebrate prey of roughey rockfish. Snailfish were the most important prey fish, comprising 45

ALEUTIAN ISLANDS

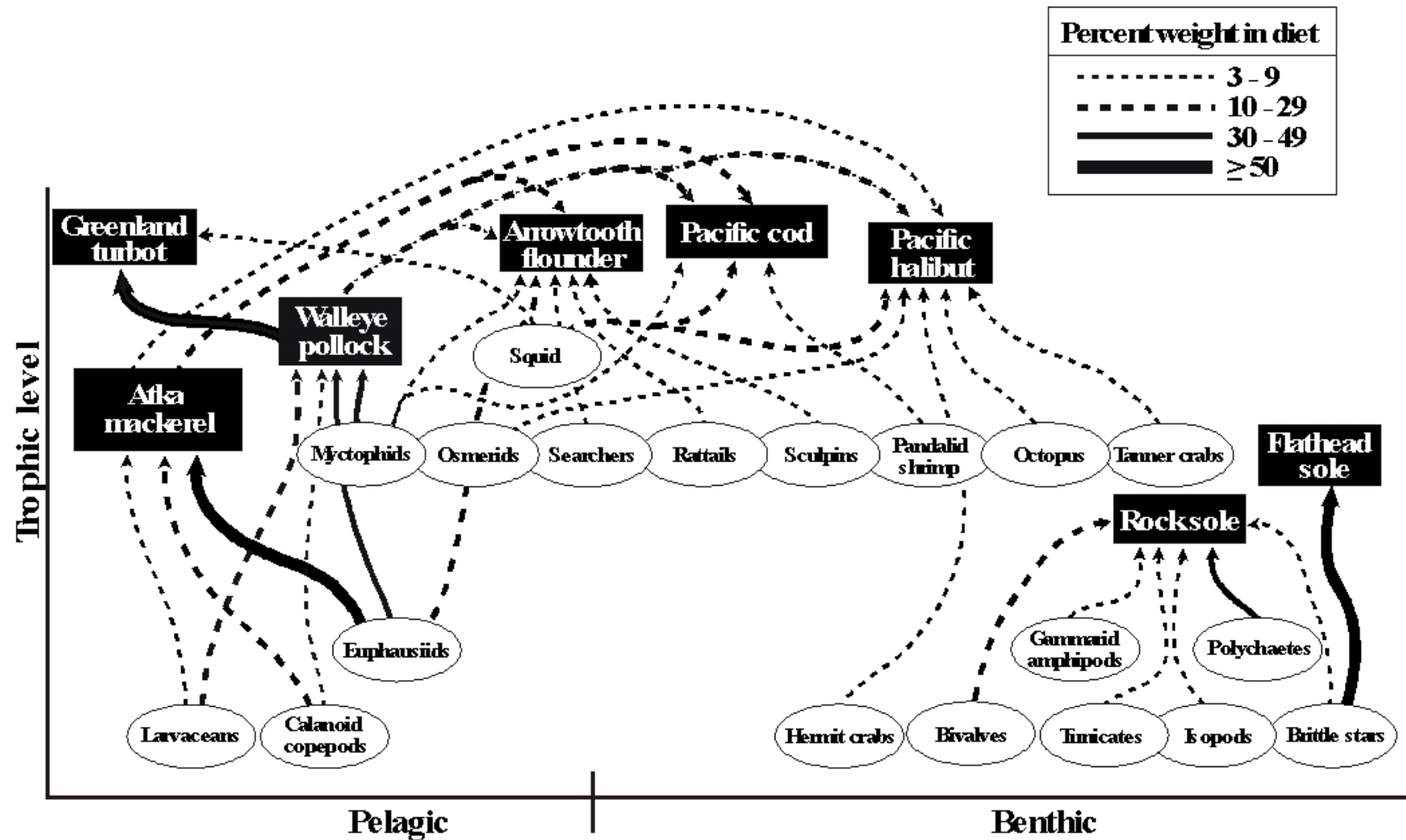


Figure 3.3-12 Trophic relationships of the groundfishes in the Aleutian Islands. Source: NMFS

percent of stomach content weight. Roughy rockfish also consumed some myctophids (4 percent). Other food items included polychaetes, amphipods, mysids, euphausiids, and isopods.

Shrimp (32 percent) were the most important food of shortraker rockfish. Fish prey comprised 37 percent of total stomach content weight, of which myctophids and cottids comprised 15 percent and 19 percent, respectively (Yang 1996). Cottids were the most important prey fish of shortspine thornyhead, comprising 51 percent of total stomach content weight. Pandalid shrimp, at 18 percent of total stomach content weight, were the most important invertebrate prey. Shortspine thornyhead also consumed Korean horsehair crab and deep sea king crab.

Non-target species, such as great sculpin, blackfin sculpin, and red Irish lord, can be categorized in this group. Simenstad et al. (1977) found that the horsehair crab and *Chionoecetes* sp. were the main food of great sculpins, fish, amphipods, and polychaetes were the most important food for blackfin sculpins, and red Irish lord fed mainly on horsehair crab, shrimp, amphipods, and polychaetes.

Grenadiers generally prey on locally abundant fish and invertebrates and scavenge for carcasses (Okamura 1970, Percy and Ambler 1974, Drazen et al. In press). Giant grenadiers feed on squid, bryozoans, fish, and shrimp around the Aleutian Islands (Novikov 1970). Pacific grenadier feed and are most commonly caught near the bottom (Percy and Ambler 1974, Buckley et al. 1999, Drazen et al. In press), but the diet of five specimens caught in a mesopelagic trawl in this region contained myctophids, other mesopelagic fishes, mysids, isopods, and euphausiids (Simenstad et al. 1977).

Pelagic Piscivores

Arrowtooth flounders and Greenland turbot are categorized in this group. In the Aleutian Islands area, prey fish comprised 89 percent (by weight) of the diet of arrowtooth flounder. Atka mackerel was reported to be the most important prey (Yang 1996), comprising 44 percent by weight of the total stomach content. Other prey fish included 13 percent walleye pollock, 7 percent myctophids, and small amounts (no more than 3 percent) of cottids, sablefish, rockfish, stichaeids, Pacific herring, snailfish, flatfish, Pacific sand lance, and viperfish. Invertebrate prey of arrowtooth flounder included small amounts (no more than 5 percent) of euphausiids, squid, and shrimp (Figure 3.3-12).

In general, the diet of Greenland turbot had high percentages of both fish and squid. Yang (1996) reported that the diet of Greenland turbot included 46 percent (by weight) squid, 28 percent walleye pollock, 13 percent bathylagids, 4 percent octopus, and 3 percent viperfish (Figure 3.3-12).

Non-target species, such as great sculpins can be categorized in this group. Simenstad et al. (1977) found that this species was completely piscivorous, with red Irish lords, sturgeon poachers, and searchers as their favorite prey.

Pelagic Zooplanktivores

Atka mackerel and northern rockfish are categorized in this group. Each species feeds mainly in the water column; zooplankton (euphausiids, calanoid, copepods, larvaceans, and hyperiid amphipods) comprised more than 60 percent of the total stomach content weight. High dietary overlap was found between Atka mackerel, Pacific ocean perch, and northern rockfish, since all consume large amount of euphausiids and calanoid copepods (Yang 1996).

Yang (1996) found that euphausiids were the most important prey of Atka mackerel in the Aleutian Islands, comprising 55 percent of total stomach content weight. Other zooplankton consumed by Atka mackerel included 17 percent calanoid copepods, and 5 percent larvaceans (pelagic tunicates). Squid was another invertebrate prey of Atka mackerel; they comprised 8 percent of total stomach content weight (Figure 3.3-12).

Euphausiids were the most important prey of northern rockfish, comprising 50 percent of the total stomach content weight. Calanoid copepods comprised another 17 percent. Other food included polychaetes, pteropods, amphipods, shrimp, hermit crabs, and larvaceans.

Non-target species that are pelagic zooplanktivores include mesopelagic fishes such as myctophids and bathylagids. Simenstad et al. (1977) reported that calanoid copepods and hyperiid amphipods constitute the major food sources of myctophids, with euphausiids, chaetognaths, pteropods, and shrimp as secondary foods. California smoothtongue fed on chaetognaths and calanoid copepods, with a secondary contribution from euphausiids.

Pelagic Mixed Zooplankton and Fish Feeders

Pollock is categorized in this group. Yang (1996) found that pollock fed mainly on euphausiids (43 percent by weight). Myctophids (37 percent by weight) were the most important prey fish of pollock in the Aleutian Islands. Less important pollock prey included calanoid copepods, shrimp, capelin, bathylagids, and Pacific sand lance (Figure 3.3-12). Although Pacific ocean perch is primarily zooplanktivorous in the GOA, it has a significant fraction of fish in its diet in the Aleutian Islands. Therefore, it is placed in this mixed zooplankton and fish feeders group. Yang (1996) reported that euphausiids were the most important prey of Pacific ocean perch, comprising 51 percent (by weight) of the diet. The next important zooplankton prey was calanoid copepods, comprising 7 percent of stomach content weight. Myctophids were the most important prey fish, comprising 34 percent of total stomach content weight.

Non-target species such as sockeye and chum salmon can be categorized in this group. Simenstad et al. (1977) reported that these salmon fed on forage fish such as Pacific sand lance and myctophids. Hyperiid amphipods and calanoid copepods also contributed to the salmon diets.